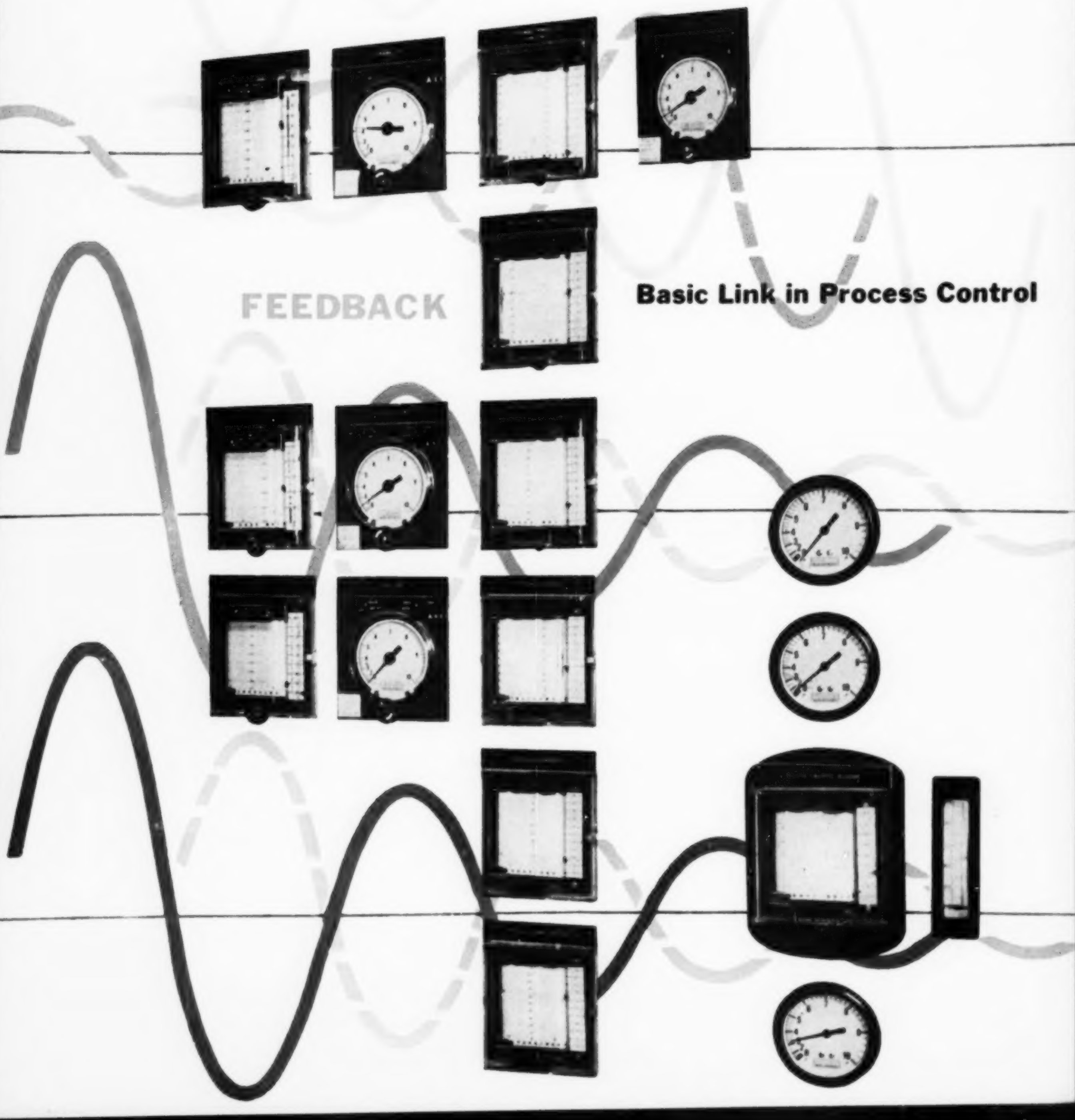
Chemical Engineering Progress

OCTOBER 1954



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Chemical Engineering Progress

OCTOBER, 1954

VOLUME 50, NO. 10

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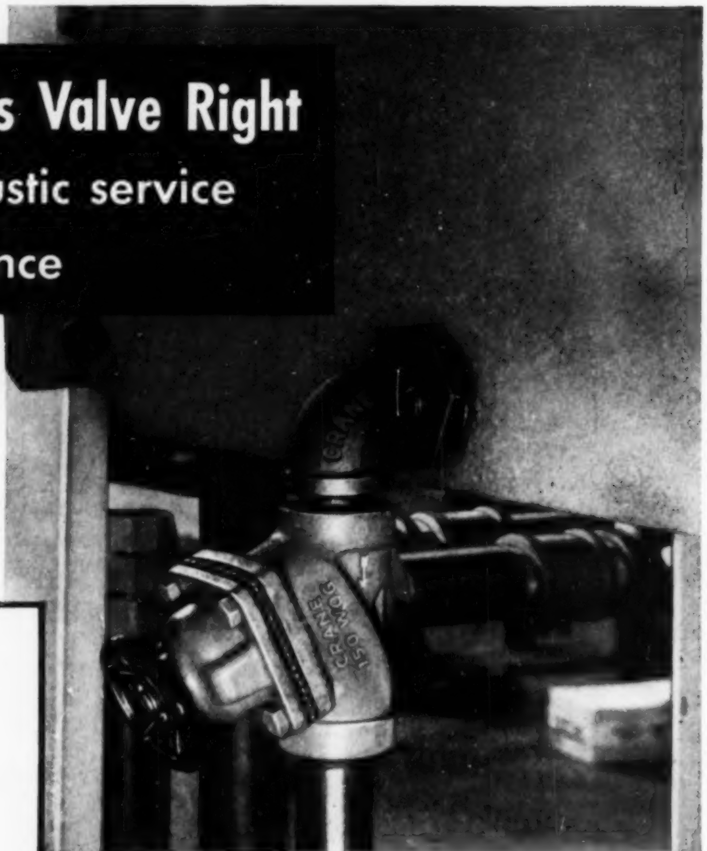
3 Years Prove This Valve Right
for this gritty caustic service
for instance



The Installation

On Trucleen dry cleaning machine, product of the American Laundry Machinery Co., Cincinnati, using Crane Diaphragm Valves as standard specification on 100° F. strong soap solution drain lines.

Valve Service Ratings

SUITABILITY: Outperforms all valves tried

FEATURES: Sealed-to-fluid bonnet

MAINTENANCE COST: None

SERVICE LIFE: No replacements since adopted 3 years ago

OPERATING RESULTS: Better machine operation—more satisfied users

PRICE: No premium

AVAILABILITY: Catalog item—No. 1610

The Valve

The diaphragm in Crane packless valves does one job only—sealing the bonnet. Independent disc does the seating—saves wear and tear on the diaphragm—permits closure of the valve even should diaphragm fail. Choose these valves from wide variety of body and trim materials—including linings—for corrosive, erosive, and ordinary services. Full information in new booklet; ask your Crane Representative for a copy.

The Case History

Conventional valves were previously used. Not until Crane Diaphragm Valves were tried was their designed-in superiority for this service fully realized. Working parts of the formerly used valves were constantly exposed to the effects of the gritty sediment solution. Seats, stem, even packing were subject to accelerated wear. The soapy solution would settle and build up in the bonnet.

Not so with No. 1610 Crane Diaphragm Valves. Their bonnet and working parts are completely sealed to line fluid. Their pliable Neoprene disc insert absorbs and seats tightly on foreign matter that quickly damages conventional valves.

Standard equipment on Trucleen machines now for more than three years, Crane Diaphragm Valves show this record: not one bit of trouble . . . no leaks . . . no repairs . . . they're absolutely right for the job—at a no-premium price.

THE BETTER QUALITY . . . BIGGER VALUE LINE . . . IN BRASS, STEEL, IRON

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CRANE CO., *General Offices:* 836 S. Michigan Ave., Chicago 5, Illinois
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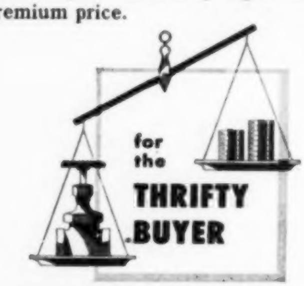


VALVES • FITTINGS • PIPE • PLUMBING • HEATING

CHEMICAL PROCESS NEWS

PUBLISHED BY CHEMICAL PROCESS DIVISION, THE M. W. KELLOGG COMPANY — OCT.-NOV. 1954

NOTES ON PHENOL-FROM-CUMENE

Cumene, a war-time antiknock component for aviation gasoline for which Kellogg originated a manufacturing process and built a number of plants, is again in the news. Currently the company is building a plant, after having developed the mechanical design, in which cumene will be produced and then used as an intermediate for manufacturing phenol in the Hercules-Distillers phenol-from-cumene process.

* * *

In this process, cumene is first oxidized to form cumene hydroperoxide. The latter is then split in a cleavage reaction into phenol and acetone, the two major products. The reaction also produces a small amount of methyl styrene.

* * *

The over-all process is an excellent example of how certain refinery products can be upgraded to industrial chemicals with a concomitant radical increase in value.

* * *

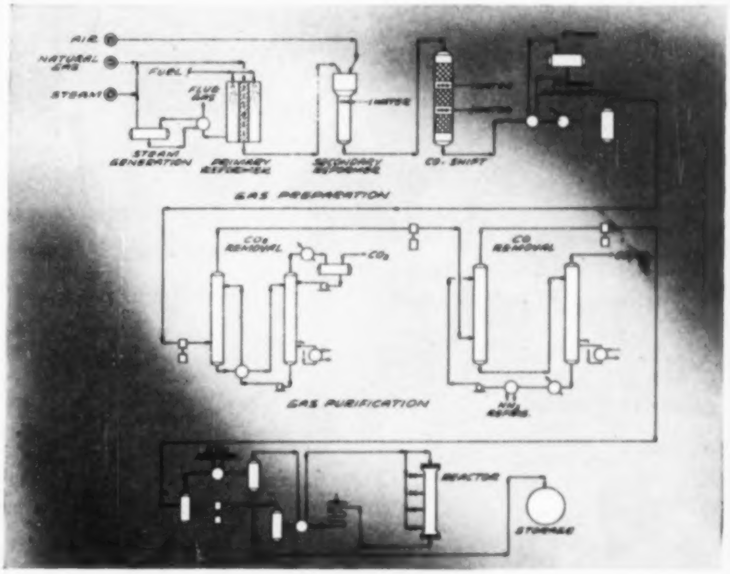
For example, propylene—a refinery by-product available at relatively low cost—makes up a third of the original feedstock volume when it is combined with benzene by alkylation to form cumene. After oxidation and cleavage, phenol is obtained from the benzene part of the initial input, and the low-cost propylene third of the input yields a substantial amount of acetone.

* * *

Thus, at present prices, acetone can be regarded as an attractive bonus for the producer—over and above the phenol produced as the major product. Moreover, the small quantity of methyl styrene made in the process can either be reconverted to cumene and used again or it can be sold to consumers in the plastics industry.

* * *

In addition to these favorable economic aspects, the process features low initial investment and operating expense. High pressures and temperatures are not used, and the consumption of chemicals such as alkalis and acids is comparatively low.



Unusually Low Investment Cost for Large, New Plant to Produce Ammonia

Kellogg has just been awarded the contract for a large ammonia plant which will make this basic fertilizer ingredient at the unusually low investment cost of approximately $50 per ton of annual capacity.

The plant, scheduled for completion in mid-1955, will be erected near Lima, Ohio, for The Standard Oil Company (Ohio). It will produce 300 tons of ammonia daily.

The major reason for the reduction in investment lies in the fact that the process employs only one ammonia synthesis section. Furthermore, operating experience with Kellogg ammonia converters has shown that they can be substantially reduced in size as can the heat exchangers without lowering capacity.

From the standpoint of operating costs, the new plant will have electrically-driven centrifugal compressors with concomitant savings in cooling water per-ton-of-ammonia produced.

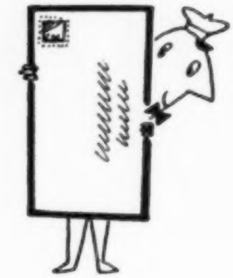
As may be seen from the flow sheet, the plant will charge natural gas to a reformer where about 70% of the feed is converted into raw synthesis gas. This mixture is then fed to a secondary reformer where nitrogen in the form of air is introduced into the stream. Heat of combustion supplies the energy necessary to reform the remainder of the natural gas.

After a quench step the mixture is fed to a gas purification section, the first process in which is a shift reaction. This converts the CO in the stream to CO_2, simultaneously producing H_2 as a result of the reaction with water in the form of steam. Carbon dioxide removal follows.

A final clean-up eliminates traces of carbon monoxide and the synthesis gas is then passed through exchange and charged to the catalytic converters.

ETHYLENE PROPYLENE BUTYLENE
METHANOL ETHANOL PROPANOL
BUTANOL ISO OCTYL ALCOHOL
BENZENE XYLENE TOLUENE
PHENOL FROM CUMENE
AMMONIA UREA
GLYCERIDES

LETTERS TO THE EDITOR



More About Reactors—A Reader's Plea

May I express a word of appreciation for the excellence of your May issue of Chemical Engineering Progress. It was a real satisfaction to be brought up to date on some of the new developments in chemical engineering as applied to the nuclear field.

Personally, what impressed me most was that many of the articles were not too technical in nature. As a former supplier of equipment to both the Manhattan Project and to the A.E.C., I feel that I can appreciate what you have done to keep us posted.

As an example, I feel that it will keep us up to date particularly in the field of reactors and would develop a feeling for the whole subject which is now so very important. There must be many chemical engineers who through changes in position cannot actively follow highly technical articles but who wish to be kept informed in a more or less general way. I hope that you can continue to publish such semi-technical articles in the various fields of chemical egineering in the future.

E. C. Bowen
Cambridge, Massachusetts

Operation Complaint

We would like to take exception to several of the statements made by Messrs. Cacosa and Leibson in the article entitled "Operation SPP" in the July issue of C.E.P.

Although we do not doubt the sincerity of Messrs. Cacosa and Leibson when they say that the SPP program has been of benefit to them, we would like to point out that their case is quite the exception and that they have been very fortunate in having drawn the assignment they did. In general SPP's are not nearly so fortunate: not only is much of the work performed by SPP's extremely boring and far beneath the capabilities of these personnel, but also

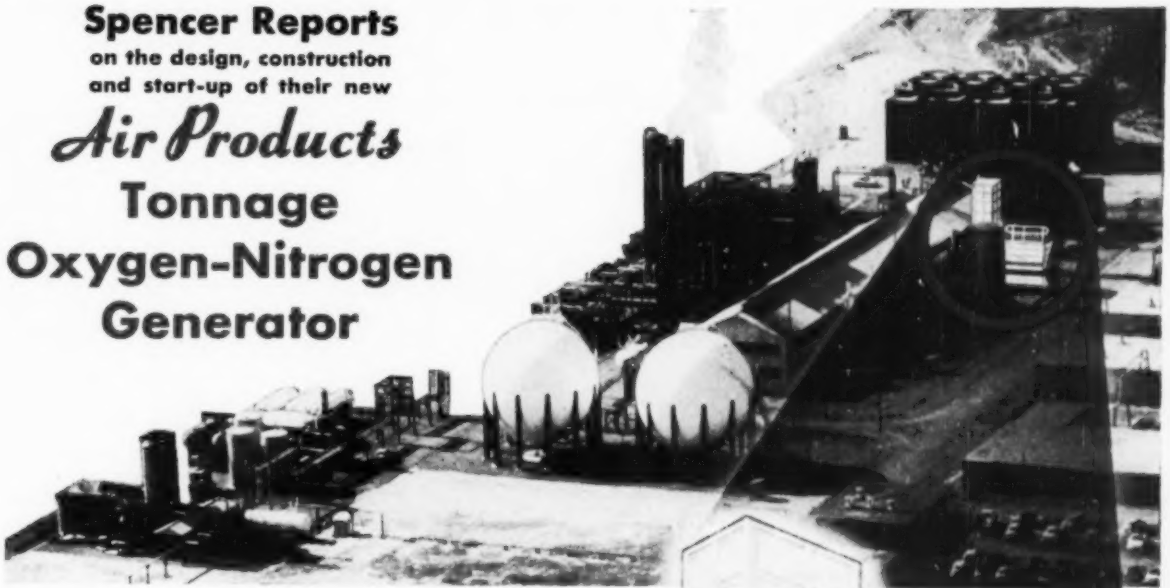
(*Continued on page* 10)

Spencer Reports

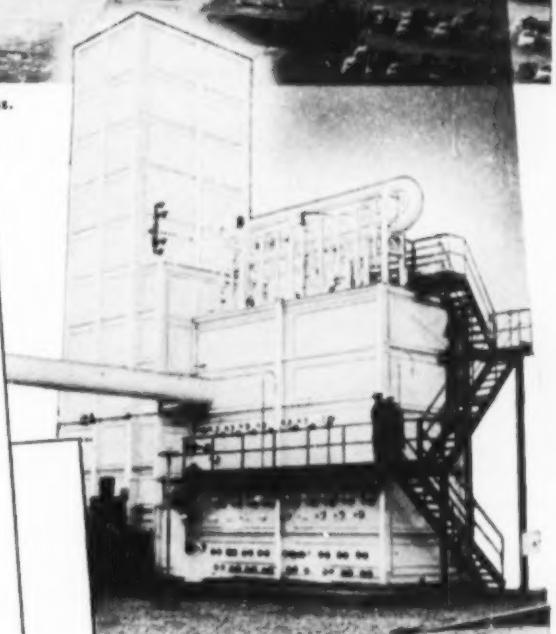
on the design, construction and start-up of their new

Air Products

Tonnage Oxygen-Nitrogen Generator



• Spencer Chemical Company's New Ammonia Plant at Vicksburg, Miss.



Spencer Chemical Company
DWIGHT BUILDING
Kansas City 5, Missouri

Mr. Leonard Pool, President
Air Products, Incorporated
P. O. Box 538
Allentown, Pennsylvania

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R. F. Brown
General Works Manager

"...I should like again to compliment you and your organization on the fine manner in which you cooperated with all of our Spencer people during the construction and start-up of the Vicksburg Unit. To my knowledge, it was a relationship which left little or nothing to be desired."

Very truly yours,

B. M. Kern
Chief Engineer

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Send for 36-page brochure, "Low-Temperature Processing"

Air Products
INCORPORATED

Specialists in Low-Temperature Processing

LETTERS TO THE EDITOR

(Continued from page 6)

there is little if any attempt to fit a man to the type of job for which he is best qualified.

While the SPP program is a step in the right direction, the mere fact that the program protects a segment of our manpower vital to the defense potential of our country cannot be taken as the justification of the program since such conservation is an absolute necessity in any eventuality. Instead the SPP program must be evaluated in terms of what it has accomplished and is accomplishing towards effectively utilizing these men in their individual capacities as SPP's. Evaluated in these terms, we say that the SPP program has accomplished relatively little and shows little promise of improving.

The statement is often made that the Army can only use a limited number of scientific and professional men in their own special fields, with the rest being used in jobs which are as close as possible to those which the men are specially trained for. This statement is true, and that is the crux of the matter, for there are extremely few cases where a man can be utilized in a job in which his special training in science or engineering is made use of. In the vast majority of cases the talents of the personnel are wasted on jobs which are well within the capacity of many non-SPP's to perform just as efficiently.

It should also be pointed out that the blame for this situation cannot be laid to the Army since the Army does not decide who should be drafted—the Army can only utilize a man as best as possible once he is drafted. The entire blame must be laid to Congress for not making a draft law which takes into account the cold, hard fact that the best chance that the United States has for maintaining peace in the world lies in keeping ahead in science and technology.

Industry should not be misled into thinking that the problem of effectively utilizing our country's supply of scientific and professional manpower has been solved in any but a very small way by the SPP program.

(Signed by) 1 Corporal
1 Private First Class
3 Privates

Engineers Can Write Better

Have enjoyed reading your series * * * wish to compliment you on the results of your efforts.

Neal B. LauBach
Hudson Engineering Corporation

(Continued on page 14)

This Tolhurst Centrifugal with "all-speed" drive is used to determine best centrifuging speeds for photographic and fine chemicals. Photo courtesy of Ringwood Chemical Company, Ringwood, Illinois.

How to find the BEST CENTRIFUGAL SPEEDS FOR YOUR PRODUCTS

Determining the most efficient centrifuging speeds can help you lower manufacturing costs and increase production. For only the *right* speeds will make the proper degree of separation in the shortest time.

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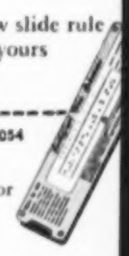

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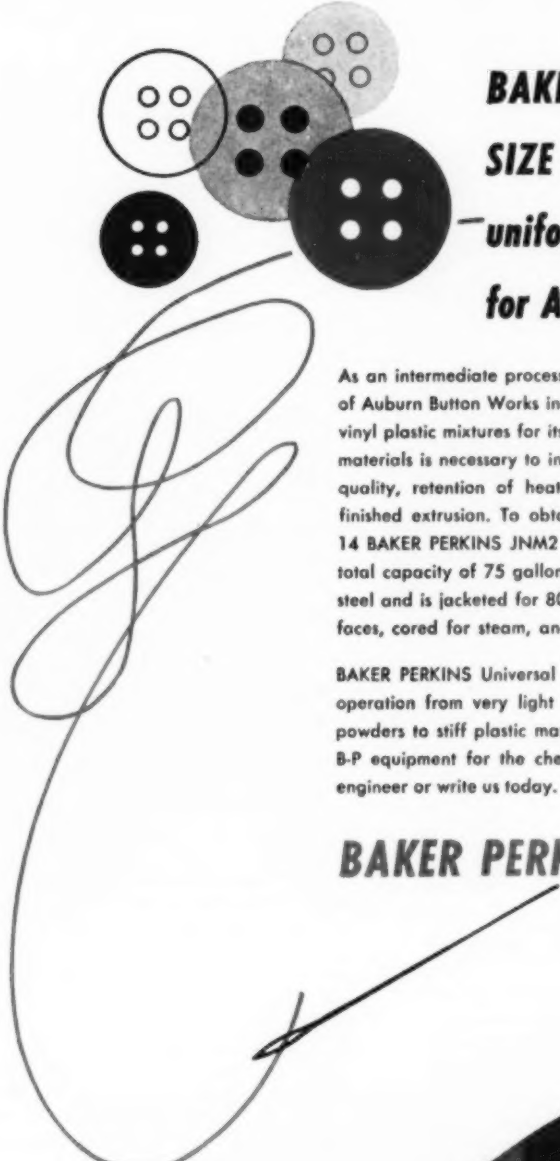
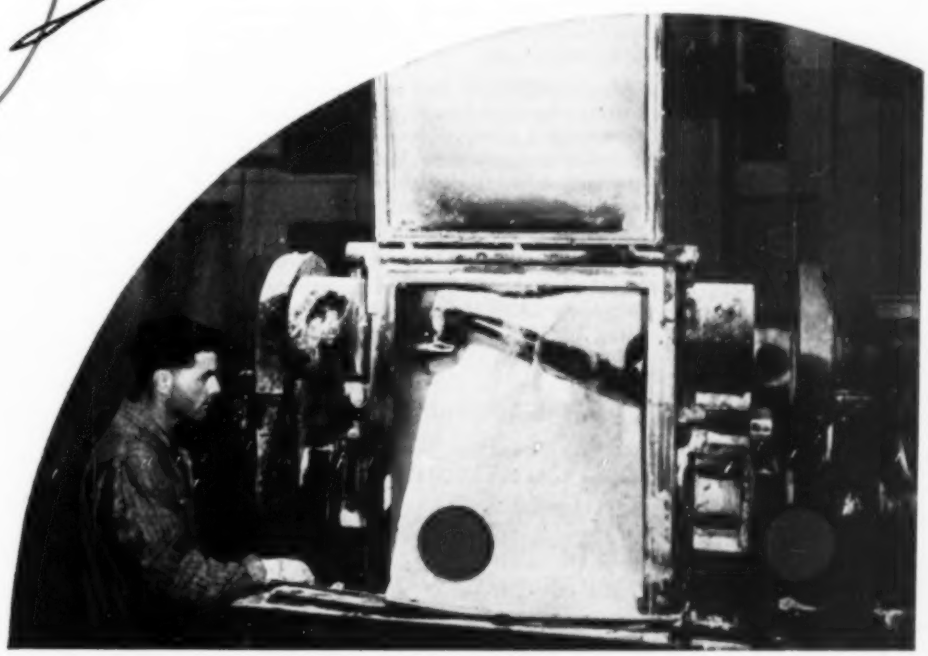




LETTERS TO THE EDITOR

(Continued from page 10)

. . . Have read with much interest your series * * * a real contribution to the improvement of writing technical papers.

Louis R. Lawson, Jr.
West Virginia Pulp and Paper Company
Development Department

. . . excellent guides for * * * chemical engineers.

Harold A. Sweet
Director, Industrial Division
Refined Products Corporation

NOTED AND QUOTED

Nothing Ventured . . .

New pursuits always involve new risks. New ventures are full of uncertainty, but the American process has always been to face boldly the risk and uncertainty and to direct a course through freedom to prosperity. Remember, you cannot steal second base and keep your foot on first base. Free men, given opportunity, make their own security, for as long as they are free the game is worth the candle and they can afford to try and try again until they succeed.

Here, then, in science and research is insurance for all of us, insurance not only good for now—it is good for all time, because the free and fertile mind, through research and development, creates more employment, more security, and higher standards than any known process.

This is the only kind of insurance that will sustain us as free people and perpetuate the processes of liberty in the great competitive race for survival among nations.

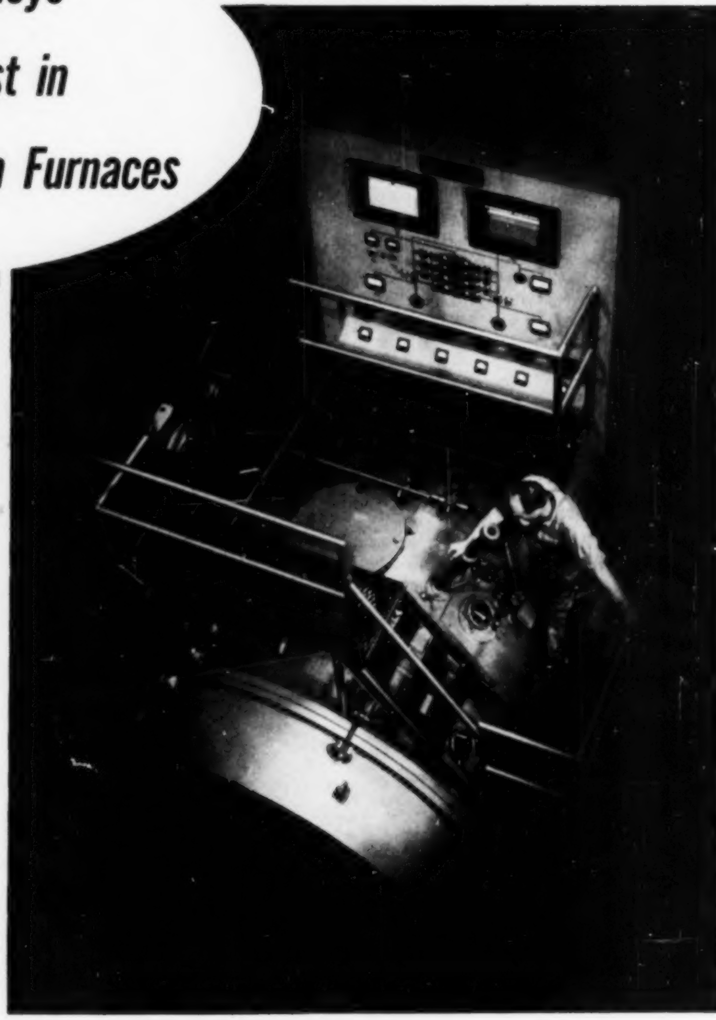
Howard E. Fritz
B. F. Goodrich Company

The Engineer and Human Understanding

I am afraid that there is a vast public relations job to be done to assist the public in understanding the real role of the university and of science. Why is it that there has grown up the widespread impression that science and gadgeteering are the same thing? Why is it that so many people—including some in industry and government—believe that the universities are in the business of making and selling gadgets? These same people have often heard that universities need money. So they naturally conclude

(Continued on page 18)

High-temperature Alloys now Melted and Cast in Stokes High-Vacuum Furnaces



A Stokes high-vacuum melting furnace of 1000-pound capacity at Utica Drop Forge & Tool Corporation, Utica, N. Y. The furnace is to be used for the melting and casting of high-temperature alloys for jet engine rotor blades.

Vacuum furnace melting and casting is the economical method for producing many new metals, with greatly improved properties. Alloys that can stand up in rocket engine combustion chambers and advanced jet engine turbines, metals essential for the construction of nuclear reactors, still other high-purity metals with properties not previously attainable . . . these are just a few of the more than thirty new elements vacuum processing has added to the industrial spectrum.

Vacuum-melted high alloy steels have greater tensile, yield, and impact strengths than conventionally-processed metal, plus greater stress-rupture strength at elevated temperatures, less creep, less brittleness. High-purity iron, processed in vacuum, has 60 to 75% greater stress-rupture strength and 400% more elongation than conventional metal. In anti-friction bearings, vacuum-processed steel has shown an increase of 300% or more in fatigue strength, and given a whole new perspective to the subject of wear-resistance.

Moreover, vacuum processing of alloys conserves critical hardening elements, since there is minimum loss of these metals during melting. More usable metal is obtained from each melt, and virtually all of the scrap can be salvaged by vacuum melting.

STOKES is *building* vacuum furnaces to process these high-purity metals in quantities up to 2000 pounds, and *planning* 5000-pound units. STOKES vacuum furnaces reflect the practical experience accumulated in fifty years of building vacuum equipment. An interesting NEW brochure is ready for mailing on request!

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NOTED AND QUOTED

(*Continued from page* 14)

that by buying a gadget from a university, they kill two birds with one stone—they get the gadget and take credit for helping the university. How can we make them see that actually they may be robbing the university?

Possibly we in science and engineering have overemphasized our gadgets—including the weapons—that we do produce. Possibly we need to get back to fundamentals in our public relations, and tell the world that the main purpose of science is not to produce bombs, guns and radar, or even refrigerators, radios, and color television. Possibly we should come out boldly and unashamedly and tell the truth—the aim of the scientist and engineer is to advance human understanding.

L. A. DuBridge
Electrical Engineering

MARGINAL NOTES

Supplements to Handbooks

Tower Packings and Packed Tower Design (second edition). Max Leva. The U. S. Stoneware Co., New York (1953), xvii + 214 pp. $8.50.

Absorption Towers. G. A. Morris and J. Jackson. Butterworths Scientific Publications, in association with Imperial Chemical Industries, Ltd., British Book Centre, New York (1953), xi + 159 pp. $3.50.

Reviewed by Thomas K. Sherwood, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Plate towers are commonly designed by the manufacturer or by engineering firms on the basis of the duty specified by the user. Packed columns are more often designed and built by the user, who must rely to a considerable extent on information obtainable in the literature. These two new books add considerably to the material available in the Perry handbook, the book on Extraction by Treybal, the book by Sherwood and Pigford, and other texts.

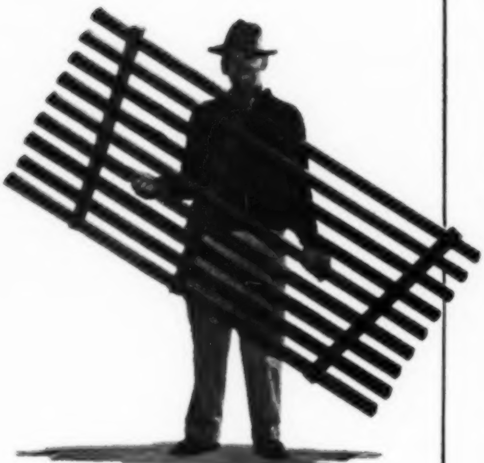
The Leva book treats tower packings, tower construction, gas pressure drop, flooding, liquid hold-up, and liquid distribution in a competent manner, with extensive reproductions of original data from the literature. Most of the important data on gas absorption in packings is also summarized. The presentation of data is much more complete than in the first edition, which has been considerably enlarged and improved.

(*Continued on page* 24)

Examine the filling of a

FLUOR COOLING TOWER

and get the whole story



Fluor uses only 100% clear all heart redwood for filling

Fluor grid decks are not only sturdily built but are made from the highest grade redwood lumber—100% clear all heart redwood—the finest cut of the log. Clear all heart redwood is free from defects and sapwood and under normal controlled water conditions will give many many years of trouble-free service. We invite you to investigate our filling before making your selection of a cooling tower.

On an average, the price of a cooling tower is based 30% on the mechanical equipment and about 70% for lumber and fabrication. For example, in a Cooling Tower costing $200,000, the mechanical equipment will amount to approximately $60,000 and the tower structure about $140,000. Of this $140,000 about 30% (or $42,000) consists of the filling (grid decks) inside the tower which breaks up the water for greater exposure to air.

The filling is in reality the heart of the tower and its design and construction is of utmost importance. All Fluor Tower filling is mill cut and assembled into grid panels, 2 ft. 10" wide x 5 ft. 11½" long. Nine bars are nailed (with 6 penny copper nails) to three 1 x 2 cross cleats. The bars are cut on a 25% bevel from 1 x 3 boards; each bar averages 1" x 1½". Grid panels are strong enough to support three 200 lb. men and are actually used as scaffolding during tower erection and inspection. You get more years from a tower with this kind of filling.

Write for illustrated bulletin
"Cooling Water for Industry."

CTI
COOLING TOWER INSTITUTE

Grid decks easily support three 200 lb. men

A 20-cell Fluor induced-draft cooling tower

A 1 x 3 makes two bars for Fluor grid decks

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Chlorine...

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Uniformly high quality GLC Graphite Anodes play an important part too—in helping the electrolytic industry meet the growing civilian and defense needs for chlorine and caustic soda.

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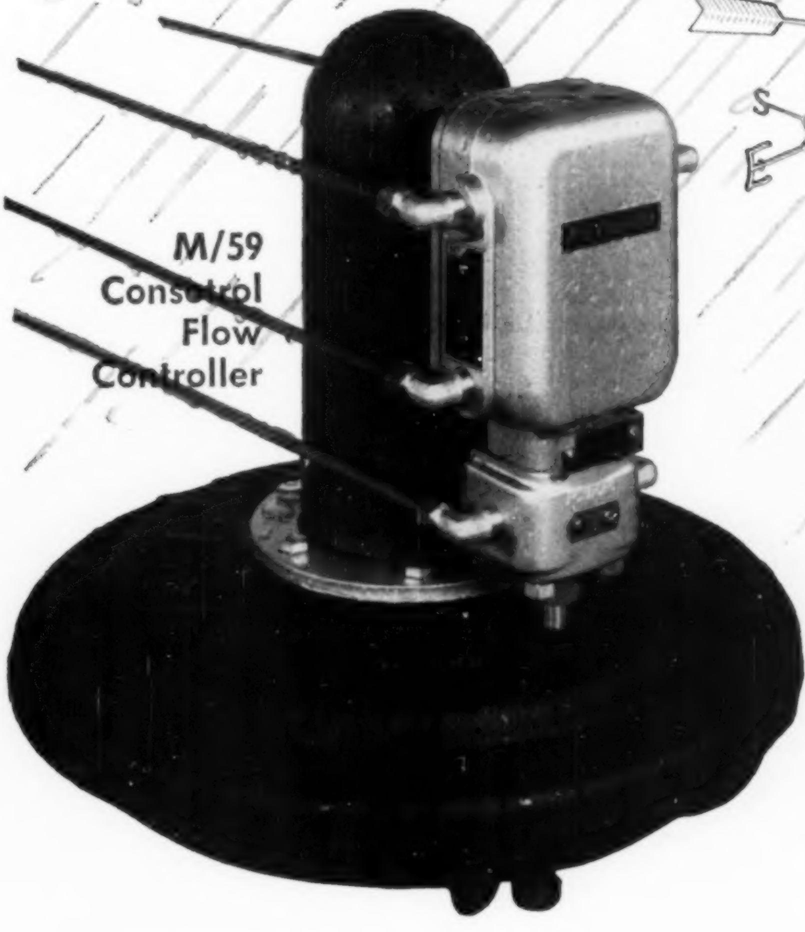
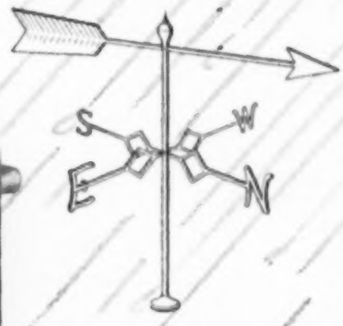
This Controller

requires no more attention than a weathervane!





Like a weathervane, the Foxboro M/59 Consotrol Controller can be installed completely exposed to the elements . . . and forgotten about! Unsurpassed in performance by any other flow controller, the M/59 is *completely indifferent to weather conditions.*

This rugged Flow Controller mounts directly on the air connection of the valve . . . at a fraction of usual installation cost. Its case is tightly gasketed, continuously purged, completely weatherproof, highly resistant to dust, fumes, and vibration. There's nothing to align, nothing to wear out. A flexure-strip fulcrum eliminates the friction and wear of conventional pivots . . . eliminates "conventional" maintenance.

In operation, the M/59 fully utilizes the speed and sensitivity of the Foxboro d/p Cell Flow Transmitter . . . does away with transmission lag . . . gives fastest recovery from process upsets. For the *complete* story, write today for Bulletin 470.

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Lowest first cost. Lowest installed cost.

Lowest maintenance cost.

Unique Simplicity — exclusive design permits fixed, optimum proportioning and reset values for liquid flows. Adjustable reset optional for gas or steam flow.

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FLUID FLOW CONTROLLERS

FACTORIES IN THE UNITED STATES, CANADA AND ENGLAND

MARGINAL NOTES

(Continued from page 18)

The book is expensively prepared, with elegant binding, paper, and illustrations. This fact and the 25 pages devoted to tables of physical properties, conversion factors, and the like make it more costly than it need be. Data on pressure drop are quoted with such completeness as to be confusing, especially since they are followed not only by general correlations, but also by a nomograph. The sections on fundamentals of mass transfer and on distillation are elementary and duplicate standard texts. The most valuable feature of the book is the material on practical aspects of tower design, since this is not available in the standard books. The error on page 40, where g_c is given as 32.2 instead of 4.18×10^8 is so gross as hardly to escape notice by the user. All in all, the book represents a valuable contribution of a kind which industry should provide more frequently, leaving colleges to concentrate on more fundamental research and writing.

The British book is less valuable for engineers trained in this country. The approach is quite empirical, with new correlations of absorption coefficients not supported by comprehensive comparison with data. The section describing the use of laboratory tests to obtain design coefficients is interesting, though not convincing. The recommended minimum liquid rate to wet packing is given as 0.85 cu.ft./(hr.)(ft. of packing perimeter), which seems much higher than often used with success. Rate coefficients and transfer units are given equal treatment, though this means duplication. As in the Leva book, the best sections deal with practical design features, including grids, which are neglected in most other works. One cannot help but wonder how much the design procedures described really represent the practice of I.C.I., as claimed.

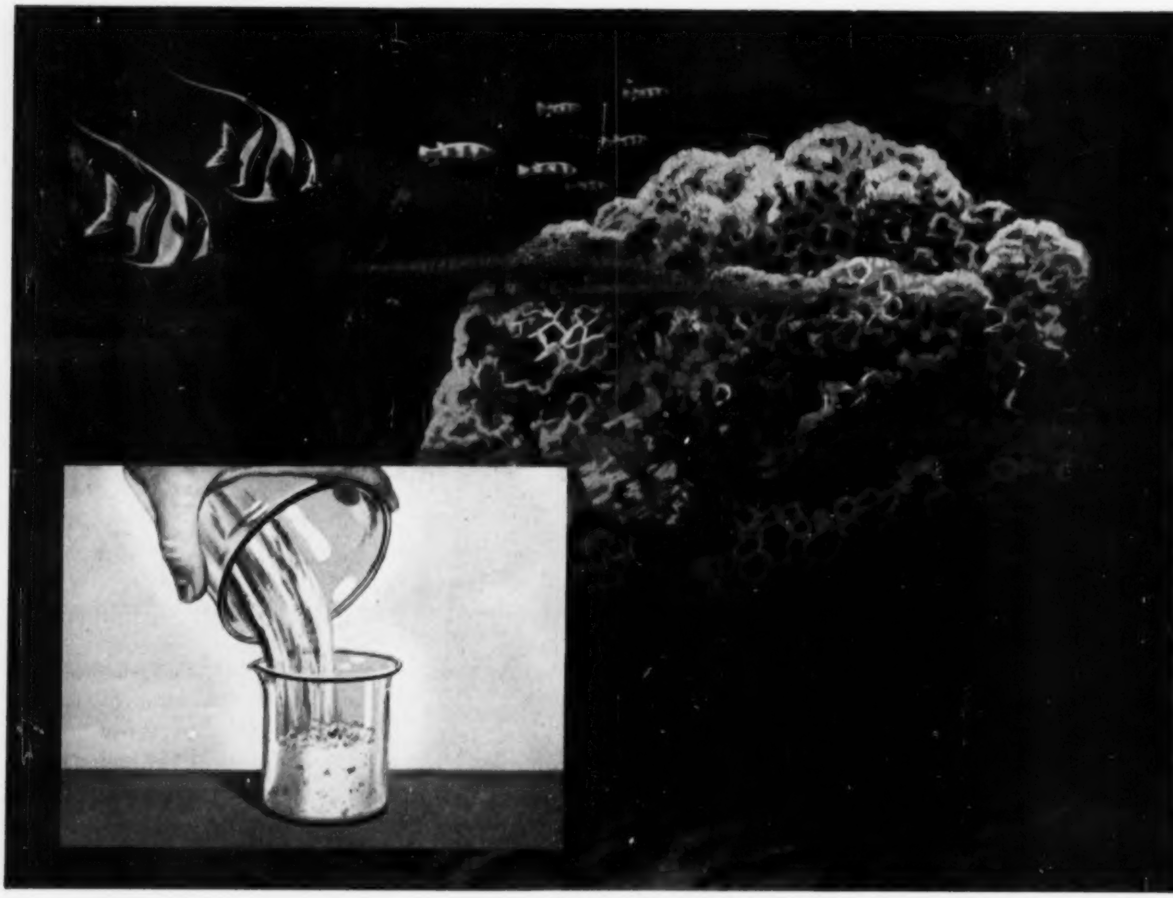
More Descriptive Than Quantitative

Materials and Proceses. Second Edition, James F. Young. John Wiley & Sons, Inc., New York (1954), xiii + 1,074 pp. $8.50.

Reviewed by James Donovan, Treasurer, Artisan Metal Products, Inc., Waltham, Mass.

This book is one of a series written in the interest of the educational program of the General Electric Co. The text of more than 1,000 pages pulls together a reasonable amount of descriptive information and some data on a large number

(Continued on page 30)



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MARGINAL NOTES

(*Continued from page 24*)

of subjects which are considered to cover the fields of materials and processes, largely in the industrial field, and definitely excluding building construction.

The "Materials" part of the presentation covers ferrous and nonferrous metals; alloys; some metallography; mechanical, corrosion and electrical properties of metals; and plastics, rubber, ceramics, etc. The "Process" section covers castings, powder, metallurgy, heat treating, hot and cold metalworking, welding, machining, cleaning, plating and finishing.

Since each of the topics covered is of itself the title of many worthy tomes, it is evident that this presentation is very condensed, is at points sketchy, and is not a reference work on any subject. However, it is recommended for those who wish a well-done presentation useful in the in-plant training of engineers by giving them an all-round understanding of the basic materials and material processing involved in the manufacture of industrial products. It definitely is stronger than a survey, but contains far less knowledge than the standard references on any of the individual subjects. It rather naturally tends to be descriptive with only a small amount of quantitative information. It points out areas of usefulness of particular techniques but is not definitive or strong in many of its statements.

Report AECU-2900, "Proceedings, University Research Reactor Conference," held at Oak Ridge, Tenn., Feb. 17-18, 1954. Edited by W. W. Grigorieff. Available from Office of Technical Services, Department of Commerce, Washington 25, D. C., vi + 221 pp. $1.35.

The proceedings consist of a collection of some twenty-six talks presented at the conference. This book should be well worth the cost to engineers interested in the reactor business and especially to those contemplating embarking on a University Research Reactor Project. The primary purpose of the conference was to present the status of research reactor technology to academicians and others engaged in nuclear research, and that subject is well covered. In addition, the sociological and political factors bearing on reactor construction, the type of research one does with a reactor, and present plans of various universities for building reactors are included in the talks. In general the book presents a good survey of the University Research Reactor field as it stands today and a good addition to a nuclear engineering technical library.

Opinion and comment

WHO IS RESPONSIBLE FOR THE INSTRUMENTATION OF PROCESS PLANTS?

Increased emphasis on the application of automatic control functions to processing operations has raised the question: Who decides what will be done? Certainly this question is one that deserves an answer, considering the increasing complexity of available instruments and the specialized knowledge about their workings possessed by the instrument engineers.

The basic problem seems related to size of plant. Small plants don't often afford the luxury of an instrument specialist, and don't have the magnitude of control problems compared with larger, more complex plants involving interrelated units. On the other hand large plants with their advantages of larger staffs of specialists can have more complicated organizational structures—making the job of formulating a reply to the basic question downright difficult.

We thought it well to ask one of the major process operators (in the large plant category above) how the responsibility is apportioned. The question was put to B. Ross Nason of Monsanto. Ross is a member of the Institute who has recently transferred from the former Merrimac Division, where he had a good deal to do with process control matters at first hand, to St. Louis, where he is now assistant director of engineering in the Inorganic Division. We quote from Ross' letter:

"In general, our process engineers develop the process requirements and functions for the various instruments, and then this information is passed on to the instrument engineer. This information will also include data on any special materials of construction that may be required. Based on this information, the instrument engineer prepares the detailed specification, obtains quotations and makes the selection in conjunction with the process engineer who must be satisfied that the selection will perform the desired function. In cases where there is a critical, unique or new function to be performed, the production or research departments—or both—in addition to the engineering people, must be satisfied with the selection."

All of this would seem to make good sense, as it utilizes the specialized knowledge of both process engineers and instrument engineers. It does not expect the chemical engineer, who is already specialized when he qualifies to his job title of "process engineer," to attempt to be familiar with the myriad details of available control instruments. On the other hand, it does not expect the instrument engineer to have in his possession the voluminous technico-economic knowledge upon which over-all decisions affecting costs and operation of a modern process plant, so vitally depend.

In these days of rapid advances in the technology of automatic process control, let us not be carried away by feelings that the ultimate benefits will be arrived at swiftly by concentration on control developments alone. Unless undertaken to meet requirements practical to the conditions of process plant operation, such developments stand the chance of expensive modification or outright failure, if not being outmoded in the time interval consumed. Once developed, however, their commercial acceptance depends on the degree to which the following realistic objectives can be met: "Reduction of production costs, increased capacity or improved quality of production from an existing process, or increased safety"—again to quote Mr. Nason.

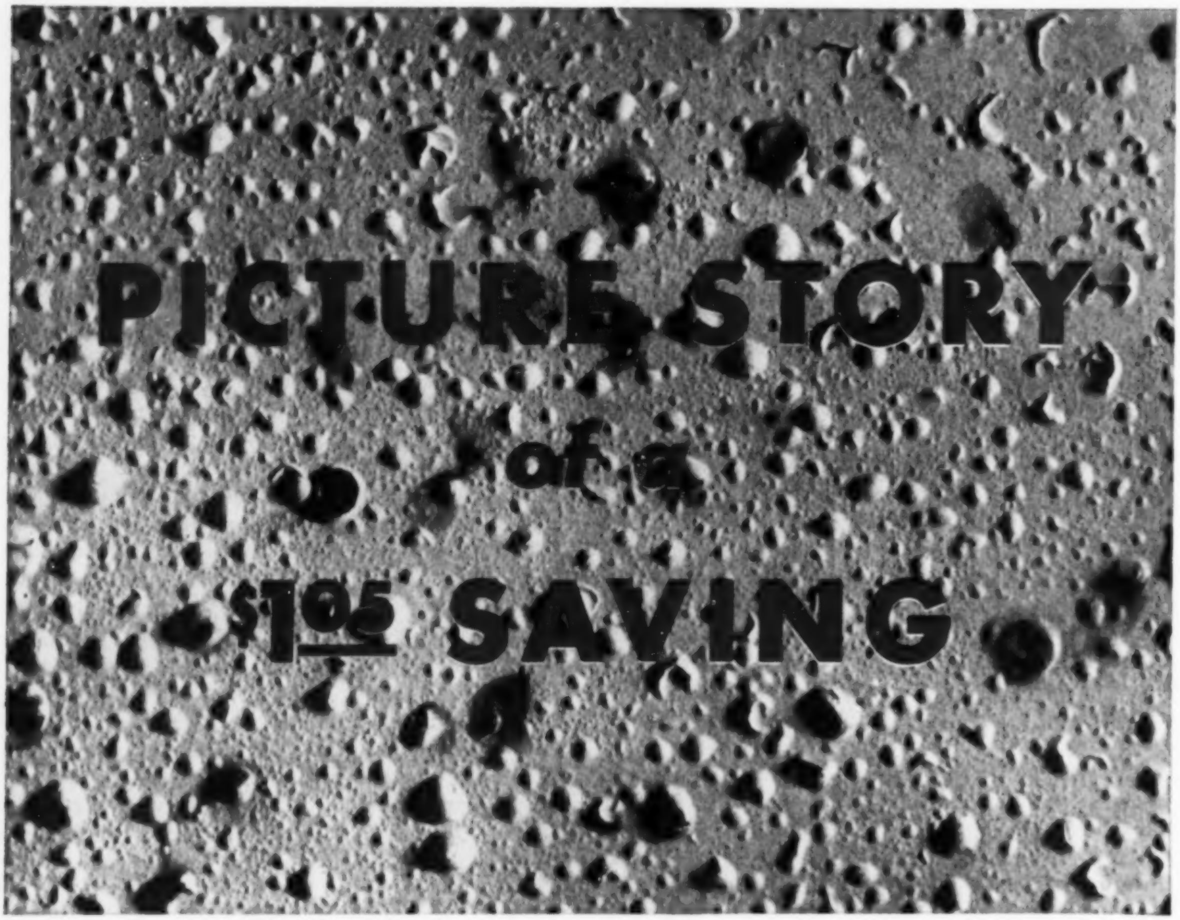
To insure keeping on the track of practicality, the instrument developer should seek guidance from the chemical engineer. And as to the matter of acceptance of product, one may rest assured that those who watch over invested capital will hold responsible for all important automation decisions, the men who know processing best—the chemical engineers.

P. S. TO INSTRUMENT MANUFACTURERS

Mr. Nason has this final word: "Over the years we have found that instrumentation is becoming increasingly necessary and complicated although we expend every effort to keep it as simple as possible. The chemical industry is presently in a highly competitive market, which seems likely to continue for some time. In such a market product quality is vital, and often specifications are sufficiently rigorous that the old style manual-controlled operation can no longer meet them. This means that reliable instrumentation is a necessity. The key here is reliability. The instruments must be tough, durable, accurate and dependable in order that out-of-service time for maintenance is at a minimum. Instrument construction should be as simple as possible in order that repair, when required, can be performed quickly by the plant maintenance group.

"As an alternative on this maintenance problem, we are watching with interest the development of the so-called "plug-in" line of instruments. With standardization this would permit removal and plug-in of a spare unit very quickly when trouble occurred, thereby minimizing out-of-service time and allowing time for repair without pressure."

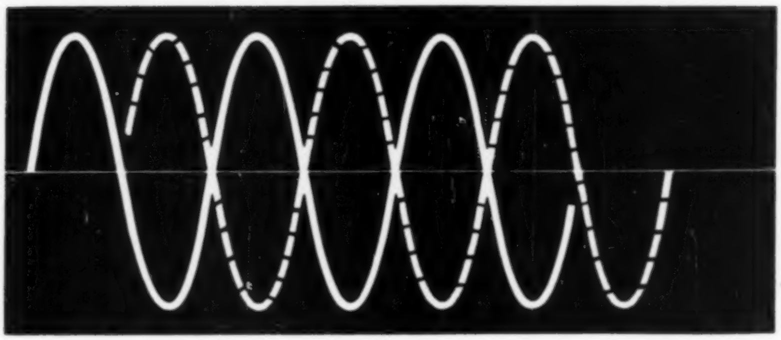
J. B. M.


PICTURE STORY
of a
$1.05 SAVING

a systematic approach to chemical process control problems

L. A. Beaudry and S. D. Ross

Minneapolis-Honeywell Regulator Co., Industrial Division, Philadelphia 44, Pa.



Since World War II the technology of automatic control has advanced so rapidly that few chemical engineers have been able to keep abreast of its recent developments. This is perhaps a matter of little consequence in the life of the average chemical engineer, for his immediate interests lie in the process itself rather than in its control devices.

Once a control system has been applied to the process, however, there can be no separation of the two and both, in the end, become his sole responsibility.

One of the most recent advances in control theory recognizes the ultimate interdependence of control and process, both of which are considered as essential parts of a single system. This of course is not an original concept since the systematic approach to the solution of problems is as old as the human mind. But System Engineering—as we shall call the new concept—employs some tools that are both new and practical. The frequency-response technique, for instance, has been used to *measure* the performance of process equipment and control devices, to assign numbers to this measurement which then can be added together to *predict* the performance of a complete system.

Language of System Engineering

To understand the language of System Engineering, one must first comprehend the basic principles of feedback control. A look at a simple closed-loop automatic-control system will illustrate this language of System Engineering and explain its basic concepts.

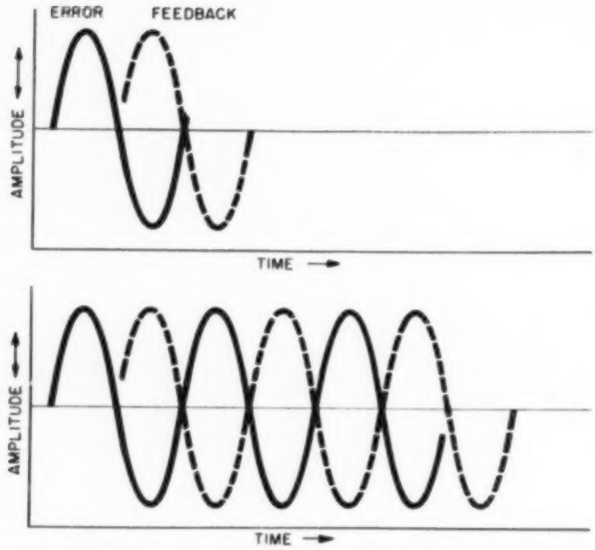


Fig. 3. Self-perpetuating oscillation.

CLOSED LOOP

Almost any automatic control system is arranged in a loop circuit, i.e., a series of components that, when combined, form the over-all control system. In a typical temperature-control system, for example, the control loop consists essentially of process, thermocouple, controller, and control valve. (Figure 1). The loop circuit is more obvious in the block diagram of Figure 2. It is possible to trace a signal applied at any selected point in such a closed loop through every component in the system and, in time, arrive back at the starting point. If, for instance, there is a change of temperature at the process, there will be a corresponding change in the outputs of the thermocouple and of the controller which will change, in turn, the position of the valve, and thus, the temperature of the process. In other words, there can be no change in one component of the closed loop unless there is a corresponding change in all the others.

Automatic control in such a closed-loop system is based generally on this principle of interdependence between the components of the system. But more specifically, it is the result of what is called feedback. Feedback in a control system is defined as that characteristic of the system that enables it to sense the difference between the desired response of the system and the response actually obtained, and to feed this difference back to a control element in order to restore the system to the desired response. The feedback control system, therefore, functions to eliminate this difference, or error.

But there's a rub. Feedback control systems have this in common with all other physical systems, namely they deal with a transfer of energy. Whether it be the integration operation of a control instrument, the project engineer's report to management, or the transition from engineering report to production line, the transfer of energy takes time and thereby creates a time delay, or lag. In feedback control systems this time delay means that the correction of an error by such systems necessarily establishes a tendency to overcorrect by an amount that is proportional to the time delay itself. The common phenomenon of cycling or oscillation—without which feedback control engineering would indeed be a bed of roses—stems from this tendency to overcorrect first in one direction and then in the other because of inherent time delays.

OSCILLATION

In a feedback control system, the tendency to oscillate will be eliminated only when there is perfect control, i.e., when there is no time lag between the appearance of an error and its correction by feedback, and when the magnitude of feedback coincides exactly with that of the error. Any departure from these ideal and strictly hypothetical conditions contributes to oscillation in the closed loop.

To gain a better understanding of the nature of oscillation, one must consider what happens to a closed-loop system when an oscillating disturbance is arti-

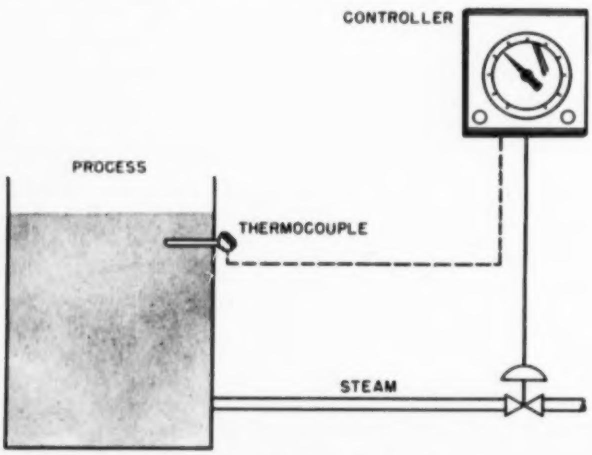


Fig. 1. Typical closed-loop control system.

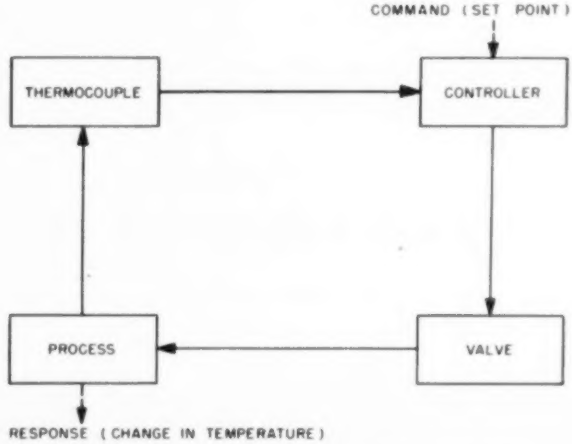


Fig. 2. Block diagram of a typical closed-loop control system.

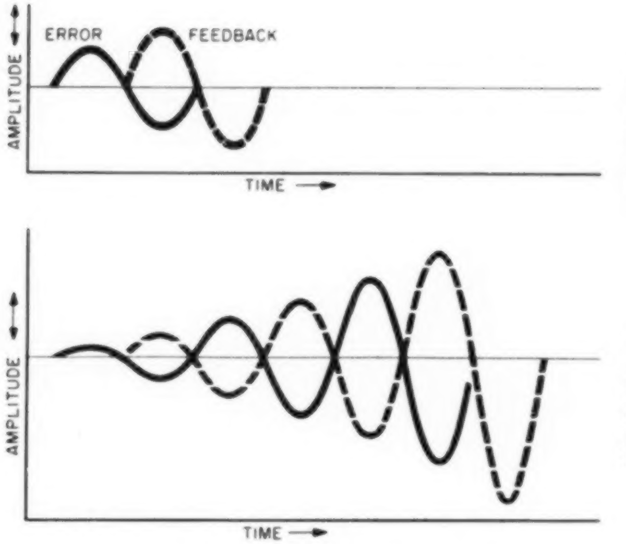


Fig. 4. Ever increasing oscillation.

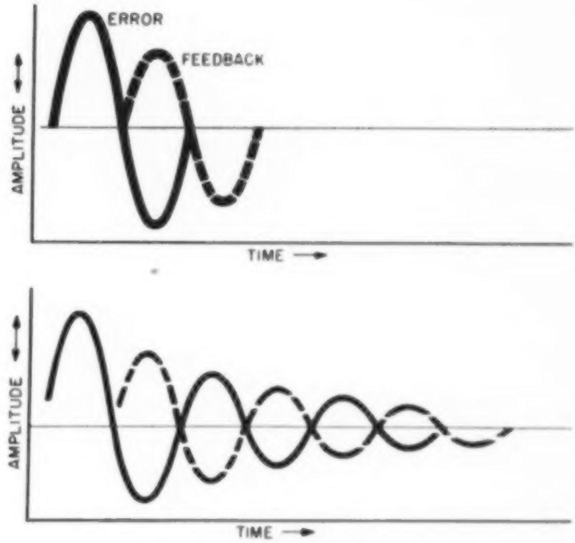


Fig. 5. Ever decreasing oscillation.

ficially imposed upon it, and the time lag of the system is such that feedback is exactly opposed in time to the disturbance. This will illustrate the three basic types of oscillation.

The first type (Figure 3) occurs when the feedback response to an oscillating disturbance or error is so delayed in time that it is opposed to the error but is neither amplified nor attenuated in quantity. The result is a self-perpetuating oscillation. (This can be proved mathematically. Without the use of mathematics however, one can see that, if the output or feedback is opposed and equal to the input, the input will be sustained without change.)

The second type of oscillation (Figure 4) will result when the feedback response to an oscillating disturbance is also opposed in time but amplified in quantity. The resulting oscillation is an ever increasing one. (Here the output is opposed to the input and amplified, and the input is therefore magnified.)

And the third type (Figure 5) will develop when the feedback response to the oscillating error is likewise opposed in time but attenuated in quantity. The resulting oscillation in a closed loop system is an ever decreasing one that will eventually die away. (In this case, the output is opposed to the input and decreased, and this results in diminishing the input.)

If there must be oscillation, the third type is obviously the least undesirable, for it contributes stability to the system by resisting outside disturbances. The other two types must be avoided since they tend to sustain or amplify the least disturbance.

Some of the more important facts about closed-loop feedback control systems can be extracted from a closer ex-

process control

amination of these three types of oscillatory behavior.

1. **The presence of a time delay in the feedback response to a disturbance is always undesirable but unfortunately is always present in physical systems. Even in the case of the ever decreasing oscillation it delays the return of the system to equilibrium.**
2. **As time delays increase, it becomes increasingly important that the magnitude of feedback be decreased proportionately.**
3. **Since control can be accurate only when feedback is of sufficient magnitude to overcome the error, it is obvious that time delays must be decreased in order that the magnitude of feedback may be increased.**

FREQUENCY RESPONSE

Frequency-response techniques for the analysis of controllability are based on this knowledge of the nature of oscillation in feedback control systems. Briefly, the technique consists of imposing, artificially, an oscillating disturbance upon a component. The feedback response of the component to the disturbance is measured both as to time lag or lead and as to amplification or attenuation (Figure 6).

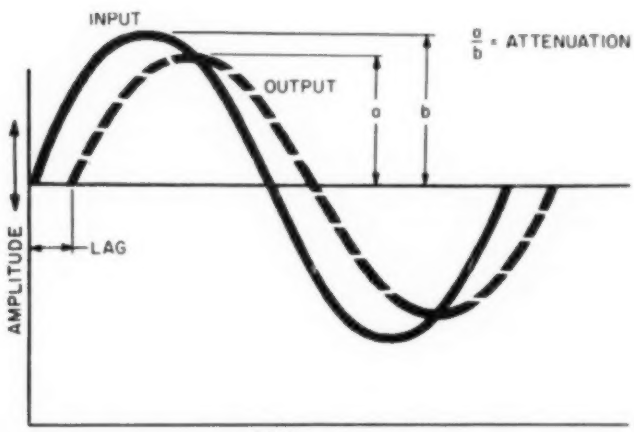


Fig. 6. Frequency response.

To facilitate the work of combining the frequency-response characteristics of individual components in order to obtain system characteristics, time lag or lead is expressed in degrees of time; and amplification or attenuation is expressed as the ratio of output to input, in logarithmic form. Thus the over-all system lag or lead is easily calculated by the algebraic addition of individual lags or leads, and over-all amplification or attenuation by the addition of the logarithmic values of the individual components.

In order to get a complete picture of the components or systems under study, a series of such tests is conducted over a range of frequencies. The range used is determined by the frequencies encountered or expected during practical operation.

With this type of information available, it is comparatively easy to predict accurately the controllability of a given system and the exact degree of control in the presence of various disturbances. Moreover, the components of a system can be similarly characterized, and the numerical data that describe their characteristics can be added together to describe the characteristics of the complete system. Cases of self-perpetuating oscillations and of ever increasing oscillations are easily nipped in the bud. Furthermore, and this is the most rewarding result of frequency-response techniques, controllability need no longer be an ever-present element of suspense in the life of process engineers. It can be measured, predicted, and *controlled*.

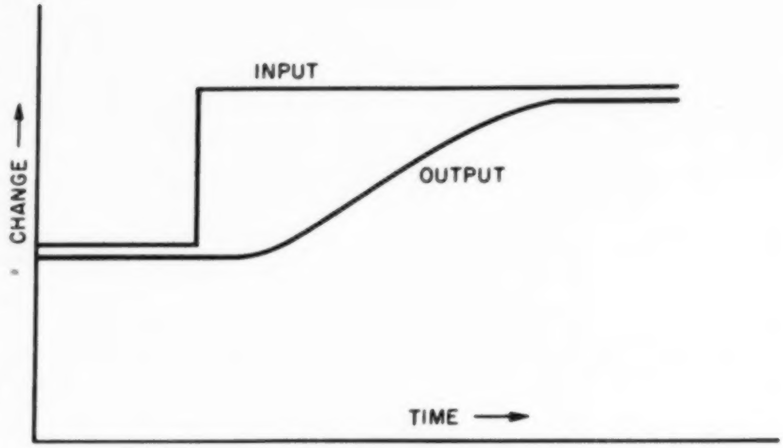


Fig. 7. Transient response.

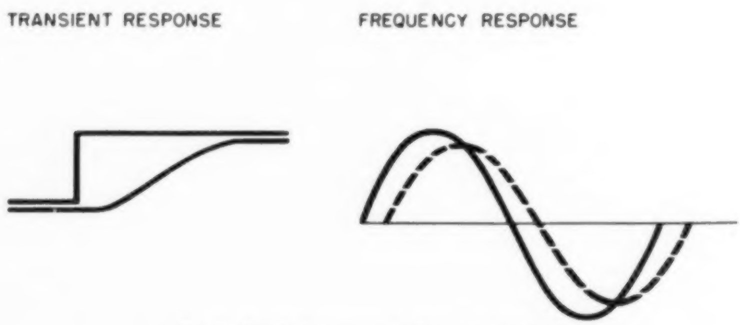


Fig. 8. Transient response vs. frequency response.

TRANSIENT RESPONSE

There is a simpler way to analyze controllability; this method does not require the specialized equipment, such as signal generators, and transducers that are necessary in frequency-response analysis. This is the transient-response technique which consists in introducing a *step* disturbance to the component under test and in measuring resultant output (Figure 7). Obviously the output will not jump instantly to the new value that corresponds to the step input but will rise gradually before it levels off. This is so because of such inherent characteristics as lag and capacity. The output curve thus obtained is descriptive of the component under test and is often called a signature curve. Empirical formulas that are specific for the component can be developed from such curves and used to predict its ease of controllability.

Although signature curves are easily obtained—or, perhaps, *because* they are easily obtained—they are not so useful to the System Engineer as a frequency-response analysis. First the signature curve, being a static analysis of the component under test developed from a single set of conditions, is obviously not applicable to all conditions of dynamic performance. Second it is difficult to combine transient-response data on individual components in order to obtain system characteristics. This is so because of the difficulty in comparing the step input curve with its S-shaped output curve (Figure 8). These limitations of the transient-response method establish the frequency-response technique as the favorite tool of System Engineering, because its sinusoidal-input and -output curves are so readily compared and combined to obtain system characteristics, and also because the results thus obtained are valid for virtually all conditions of system performance.

Benefits of System Engineering

Transient-response and frequency-response techniques are only two of the many tools that are available to the System Engineer. No single one of these tools, by itself, can be construed as a cure-all for the control problems that beset the chemical process industries.

System Engineering means an intelligent, systematic approach to any control problem and is useful in the solution of simple as well as complex problems. For the less complex problems, there are relatively simple methods of approach such as the transient-response technique; as the problem increases in complexity, methods and techniques must, of necessity, become more sophisticated, as in the case of the frequency-response method.

System Engineering can be equally useful in the evaluation of system and component design, performance, and trouble shooting, and for the development of future systems and components.

But, most important, System Engineering lends a uniformity of purpose to all the members of the process team and simplifies the problem of communication between them by providing a common language that is understood by all. This, in turn, increases the effectiveness of the team and improves process control because it fits control and process, one to the other.

Résumé of Papers . . .

What new instruments or systems using new devices have been developed for the use of the chemical engineer? If one is interested in measuring the density of liquids, solids or slurries, or detecting liquid-liquid, or liquid-solid interface while at rest or in motion, or measuring material levels without intimate contact . . . then one would be interested in the new gamma ray absorption devices such as the "ohmart cell" or the gagetron.

The problem of measuring fluid flows of corrosive liquids, liquids under high or low pressures or high or low temperatures, or of unstable compounds, or of dirty liquids, can be resolved through the use of the "floating rotor" turbine-type flowmeter of Potter Aeronautical Co., which transmits instantaneous changes in fluid flow into external electrical impulses without physical connections to its casing.

A device called the differential transformer is being used for sensing slight movements in the end of a Bourdon or a torque tube and translating this to a proportional signal. When attached to a Bourdon tube coupled to a hydraulic load cell, high tonnage can be handled in a continuous weighing of a storage tank. A device for measuring specific gravity of fluids in a pipeline can be made by attaching this differential transformer to a constant volume torque tube which continuously samples pipeline fluid.

The strain gauge—a resistance-wire device—is being used to convert pressure or weight into an electrical impulse for remote location control and may be expected to find wide application.

Low capacity flow control problems, such as the addition of resin to paper pulp, addition of a fuel oil inhibitor in precise quantities, or metering of chemicals in dyehouse water treatment, may be aided by control volume pumps.

Gravimetric feeders can be instrumented for use in continuous processing to provide accurate solutions to bulk solids handling problems.

L to R: A. A. Melnychuk, A. H. McKinney, D. B. Kendall, S. D. Ross; C. G. Kirkbride, A. I. Ch. E. president, opening meeting.

A.I.Ch.E.—I.S.A. symposium papers in review

—automatic control over materials movement

R. W. Glasheen Associate Editor

The use of instruments to assist the chemical engineer in the handling of materials was covered in eleven papers presented at the first A.I.Ch.E. and Instrument Society of America joint symposium held in Convention Hall, Philadelphia, on Sept. 23, 1954. Chalmer G. Kirkbride, president of the A.I.Ch.E., in opening the meeting lauded the efforts of the joint groups in bringing together information of current interest to both the chemical engineer and those in the instrument field interested in the development of new and better instruments as well as in systems for materials handling. The program was organized under the direction of S. D. Ross (Minneapolis Honeywell Regulator Co.), who also acted as chairman, and A. H. McKinney (E. I. duPont de Nemours & Co.), as vice chairman.

Inasmuch as it was felt that the papers contained certain information that could benefit by immediate publication in brief form, this procedure has been followed in this issue of C.E.P. Reviews of papers presented at the symposium appear in the following pages, with the exception of papers containing survey-type information by W. B. Heinz (Heinz Engineering), V. C. Kennedy, Jr. (Streeter-Amet Co.), and W. M. Young (Richardson Scale Co.).

Turbine type flowmeters in materials handling

A new type of flow sensing element made in the form of a straight section of pipe, containing a turbine rotor and easily installed in a fluid system is the Potter Aeronautical Co. flowmeter. G. Fitzpatrick in a paper discussed this unit, its operating principles, advantages, limitations, and methods of use. The device and accompanying measurement apparatus will work with any liquid where fluid velocity is a true indication of flow rate. The ability of the turbine type flowmeter to measure with extreme accuracy under conditions that preclude the use of conventional flowmeters, stems largely from its incorporation of two unique principles of operation: a patented venture design in which the downstream drag created by the flow of liquid through the blades of a rotor is balanced by an upstream thrust (which is also derived from the liquid flow), and the use of a magnet located within the rotor to produce an electrical signal without a direct coupling or follower mechanism. Difficult metering problems in systems having high pressures, both high and low temperatures, unstable compounds, dirty liquids, and highly refined fluids that must be kept completely free from contamination, are suited to this new device. In a totalizing system the accuracy of measurement can frequently be within 0.1%. In a flow rate measuring system an accuracy of plus or minus 0.5% of instantaneous flow can usually be obtained above 25% of full scale. It will measure true flow in lines whose pressure is subject to wide and violent fluctuations. The turbine type element for installation purposes is made with end fittings to match the pipeline in which it is being installed. Units smaller than ½ in. are not made.

Liquids containing suspended articles are measured accurately, the only requirement being that the particles pass freely through the element. Temperatures as high as 1200° F. and pressures as high as several thousand atmospheres have been used with excellent results. The operating range of the unit is reached when it is used to measure liquids having a viscosity of 10 centipoises or higher.

The turbine type meter (Fig. 1) consists essentially of a turbine rotor sus-

pended in a section of piping in such a manner that fluid passing through the housing spins the rotor at a rate that is directly proportional to fluid velocity. A linear relationship between velocity and speed of rotation is maintained through the use of a venturi effect to create hydrostatic balance which centers the rotor between its upstream and downstream supports, completely eliminating thrust friction. Liquid passing through the housing at point A encounters a restricting cone which is part of the upstream retaining assembly. This restriction causes a velocity increase at point B with a corresponding decrease in fluid pressure. The sensing element rotor being shaped like a cone with the base upstream permits a decrease in velocity and a subsequent increase in pressure, tending to force the rotor upstream toward the low pressure area. Excessive upstream movement is prevented by making the rotor cone slightly larger than the cone of the retaining assembly. As a result, when the rotor is correctly positioned, flow over the fixed cone begins to impinge on base of the rotor cone and prevent further movement upstream. Since further increases in velocity will increase both the pressures tending to move the rotor upstream and those tending to move it downstream, there will be no net effect on the rotor position at higher rates of flow. The "floating rotor" effect eliminates friction so that the only effect of an increase in flow is to increase rotational speed. As a result the output of the sensing element is linear with respect to flow from the point where the rotor assumes this floating position throughout the range of the unit. In the linearity curve (Fig. 2) the first point plotted at approximately seven gallons per minute, shows the effect of friction at a flow rate that is too low to cause the rotor to position itself. The cycles/gallon quantity is at this point constant within 0.5%. As the hydraulic positioning force becomes greater, the cycles per gallon figure increases until at the third point plotted the output is linear well within 0.5%. Since it is impossible to eliminate completely errors in the calibration equipment used, a slight amount of scatter is evident in the plotted curve. This can be attributed partly to nonrepeatability in the rest stand and partly to nonrepeatability in the sensing element itself.

Two basic types of instrumentation are used in conjunction with the turbine type sensing element. A flow rate measuring system makes use of the fact that the element produces a frequency output which varies directly with flow. When this output is fed into a frequency converter, a dc signal is obtained which varies directly with the rate of flow through the sensing element. This can be indicated or recorded in units of flow on a dc milliammeter or an electronic potentiometer. One type of converter is built inside the case of a standard electronic potentiometer.

In flow rate measuring systems, use is made of the fact that there is a definite ratio between flow and frequency for each flow sensing element. This makes it possible to calibrate the entire flow metering system by injecting a known freqency into the measuring circuit and making an adjustment, if necessary, so that the instrument indicates the corresponding flow rate. Calibration of the read-out instrument can be checked at any time, using a built-in frequency reference, without disturbing the flow sensing element.

Although flow rate can be measured with reasonably good accuracy—usually about 0.5 per cent of the instantaneous rate—using the system described above, the digital systems that have been devised for measuring total flow are probably of much greater interest in a discussion of materials handling.

Total flow through a pipeline, or into or out of a storage tank can be measured easily and accurately by connecting the flowmeter output to a digital counter, using a totalizer with a capacity of over 99 million pulses. The indicated total count is multiplied by a constant conversion factor in order to obtain total flow in gallons, quarts, pounds or other units. When the primary element is a turbine type sensing element and the flow rate is fairly constant, a system accuracy of 0.1 per cent or better can be provided for most applications.

To avoid conversion factors, a computing counter is available. When the correct conversion factor is set into the instrument by depressing the proper combination of keys, the output of the flow sensing element is read directly as gallons, pounds, or whatever other units are desired. It is even possible to set up this type of instrument to read the dollar value of the product being measured.

A single pulse from the turbine type sensing unit can represent as little as one thirty-thousandth of a gallon, or several gallons, depending on the size of the sensing element used. This makes it possible to control the ratio of a very small flow to a very large one with excellent accuracy. If necessary, to accommodate large volume flows at low rates, counter capacity can be extended almost indefinitely through the use of decade divider circuits or by increasing the size of the mechanical counter used.

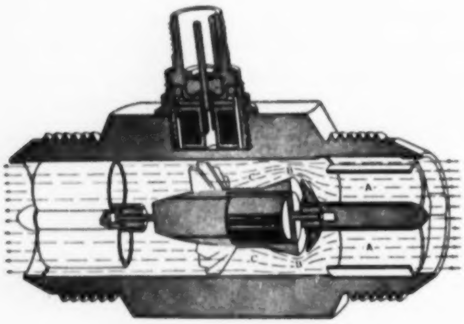


Fig. 1.

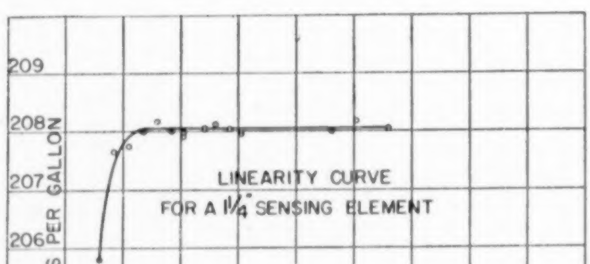


Fig. 2.

As is the case with any piece of equipment containing moving parts, the service life of the turbine type element depends largely on the conditions under which it is used. Units have operated satisfactorily without attention for several years, with no detectable calibration shift. At the same time, other units are considered satisfactory if they will operate for a few months under particularly difficult service conditions.

Generally the equipment cost for a turbine type flowmeter is higher than the equipment cost for a conventional differential or area meter. However, because of the much simpler installation, costs on an installed basis are compatible. Generally speaking, difficult applications favor the use of the turbine type meter on a cost basis as well as on the basis of performance.

Solving low capacity flow control problems

Controlled volume pumps provide the solution to many varied low capacity flow control problems encountered in process instrumentation. As flow controllers, they meter and pump process streams. As ratio controllers, they maintain fixed relations of any number of liquid flows, or ratio a liquid in proportion to a solid or gas flow. As final control elements in the control loop, they contribute to the accurate regulation of process variables. W. T. Griffiths (Milton Roy Co.) described several examples of systems employing controlled volume pumps representing problems and how they were solved with these pumps.

Means for accurately metering the low capacity (2 gal/min) flow of a wet strength resin and means for automatic dilution of a 50% alum solution in a paper plant operation are described. A combination of ratio and *p*H control was effected using several pumps to solve a water treating application where metering of controlled volumes of treating chemicals is involved along with a pumping and controlling system attached to a *pH* measuring cell for continuous sampling and control. This system solved the problem treating water at *p*H of 6.5 for optimum flocculation and yet continuously supplied water at *p*H of 8.0. In other examples, ratio control was exemplified in metering a chemical inhibitor in proportion to the fuel oil flow rate; complete automatic process control consisted in part of utilizing air powered pumps as process flow control instruments and as final control elements in a continuous polymerization process.

The problem of metering wet strength resin was solved with a pump powered by a three-quarter horsepower variable speed motor. A variation in capacity over a 9:1 range while the pump is in operation was accomplished by a manual adjustment of stroke length which permitted controlled regulation of the ratio of the resin additive, as required by changes in the pulp flow rate.

Ration control in the continuous dilution of the 50% alum solution with water to a desired *p*H was accomplished by sensing the water flow with a nutating disc in the water line and having this indication vary the stroking of the controlled volume pump metering the concentrated alum solution. The metering pump was controlled by use of an air cylinder which stroked the pump. Control of the air to either end of the double acting air cylinder was accomplished by a rotary air valve which allowed a four way air valve to exhaust or admit air to either end of the double acting air cylinder. The rotary air valve is coupled to the nutating disc in the water line. Any variation in the flow will likewise alter the stroke of the pump through the controlling linkages so that the alum is metered proportional to water flow.

In the open loop control system that solved the problem of chemical inhibitor injection, the flow of the fuel oil was measured by a pneumatic balance type meter, which transmitted an air signal in proportion to the rate of flow to a receiver-recorder-controller. The controller is equipped with a special electronic impulser which emits electrical impulses (in direct ratio to the flow) to an explosion-proof four-way, solenoid operated, air pilot valve. The pilot valve alternately admits air to either side of the double-acting four-way pneumatic cylinder, thereby pacing the pump. With this system the amount of inhibitor added is proportional to the rate of flow of the oil. The combination of pneumatic flow transmitter and air operated pump was chosen for several reasons. Complete explosion proofing was required at the oil line. Rugged equipment was needed to eliminate costly shutdown periods. In addition, high repetitive accuracy was required to effect efficient and economical use of chemicals. Since more than one grade of oil is handled by this system, a means of varying the ratio of inhibitor addition is required. Whenever a change in ratio is necessary, because of changing oil characteristics, it can be quickly and accurately made while the system is in operation by adjusting the plunger stroke length with a vernier screw adjustment on the pump.

Applications of Ohmart equipment to the measurement of process variables

A radiation absorption type system of measurement of process variables has been used in many problems in the materials handling field. Principles of operation and a description of present installations were outlined by H. L. Cook (Ohmart Corporation). Measurement of levels of liquids, solids and slurries, measurement of liquid-liquid and liquid-solid interface positions and the measurement of densities of liquids, slurries, and solids are practical with this system. An example of existing applications is the level measurement of a viscous material in a horizontal reactor vessel; another is the detection of the liquid solid interface in a crude oil coking drum; and still another is the detection of a liquid-liquid interface in a pipe line for the discrimination between gasoline and isobutane. A system is described for an automatic shut-off installation on a batch process separation vessel used for the separation of a heterogeneous fluid. In one application the density of a magnetite-water slurry flowing through a six-inch pipe was measured over a specific gravity range from 1.25 to 1.50 to an accuracy of plus or minus .005 specific gravity units with a time constant of approximately 5 seconds. As this is an electrical transducer, remote location applications are readily adapted.

In this transducer the principle of absorption of gamma radiation is utilized. For a fixed thickness of material, the absorption of radiation is a function of density. To measure the density of a material flowing in a pipe, a source of gamma radiation is placed on one side of the pipe and a detector of gamma radiation (an Ohmart Cell) on the other side of the pipe opposite the source. As the density of the material varies, the absorption of the gamma radiation will vary and consequently the signal current generated by the cell will vary. The signal current variation can be amplified to produce a deflection on an indicating meter, recorder or recorder-controller.

The major components of a typical system (Fig. 3) are the radiation source, the measuring cell, the compensating cell, which is a zero suppression device, the amplifier, and the recorder or recorder-controller. The radiation source is contained in a hermetically sealed capsule. Normally, the capsule is encased in a lead filled source holder with a rotary shutter. A positive polarity current is generated by the measuring cell and the magnitude of the current is a function of the density of the material in the pipe. The compensating cell generates a negative polarity current of fixed magnitude. The magnitude is adjustable over a narrow range to compensate for various operating conditions. As an example, a slurry density with a

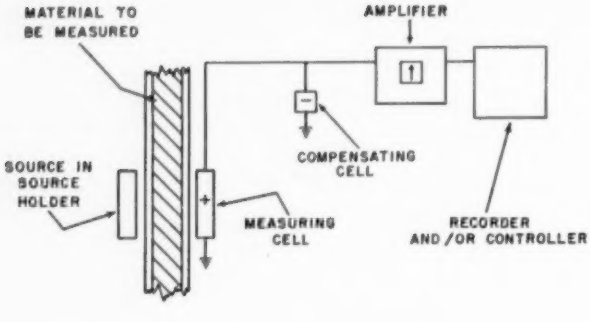


Fig. 3.

variation in specific gravity of 1.0 to 1.2 is to be measured. The measuring cell may generate a current of ten units for a gravity of 1.0 and eight units for a gravity of 1.2. The compensating cell is adjusted to generate a current of ten units which is termed the residual current. The compensating cell current of minus ten units and the measuring cell current of plus 10 units add algebraically to produce zero. Thus for a gravity of 1.0, there is zero input to the amplifier. A density of 1.2 will have a net increase of two negative units, which is called the Delta I current. The amplifier sensitivity is adjusted so that two negative units of Delta I currents produce full scale deflection and thus there is a full scale indication on the amplifier, panel meter, or recorder that indicates zero for a gravity of 1.0 and full scale for a gravity of 1.2.

Level measurements of granular solids

Measurement of the level of a granular solid in a hopper such as would be encountered in feeding a catalyst in a catalytic cracking unit was discussed by F. S. Becker (Sun Oil Co.). The use of a radiation detection device, the gagetron, from its original development to its present improved state was illustrated through examples of installations using these techniques. The fundamental physical principles of the sensing operation were described. The gagetron has proven that it will safely measure level in the most difficult and hazardous processes and has the advantage that it can be repaired or replaced without shutting down the process. Another type of level instrument described, operates on a capacitive principle. It will give a more accurate and constant level reading in those processes where a probe can be designed to withstand the operating conditions involved. Processes using capacitive probes must be shut down for instrument replacement.

The gagetron operates as a level control because material in the path between a radioactive source of gamma radiation and a detecting geiger-tube varies as the level varies. The amount of material in the path of the radioactive geiger-tube circuit is indicative of the amount of gamma radiation absorbed and how much of the radiation will get through to develop an electrical signal. In a typical application the radiation cells are positioned in a spiral direction up the hopper walls. Locating individual sources vertically or spirally on the hopper wall permits a level indication through detection of how much of the anticipated radiation is not absorbed.

In using the gagetron system, care must be taken in properly spacing the radiation sources in a vertical path in the container. Radiation intensity varies inversely as the square of the distance from the source. It is therefore necessary to increase the amount of radium (in the case described) in each source below the top source in order for it to produce the same increment of level variation at the top source. The total of gamma radiation of all the sources must not be more than about 100 counts per second which is the maximum for which the geiger tube is normally designed.

In a typical installation the spacing between radium sources was two feet. The counter tube was mounted two feet above the top source. It must be remembered that a temperature over 200° F will materially shorten the life of the counter tube.

The capacitive type level instrument operates due to a change in dielectric material between two plates of a condenser. One plate of the condenser is in the form of a metallic rod inserted vertically in the hopper. The other plate of the condenser can be the side of the hopper bin or another rod placed in close proximity. As the level varies the total capacitance of the system varies due to a changing dielectric constant.

Another capacitive instrument varies by having a fixed dielectric such as teflon on the metallic rod with the variation in capacitance due to the change in the size of the second plate caused by varying the height of the hopper.

The application of SR-Strain Gauges to materials handling

Use of resistance-wire strain gauges in measuring pressure in crude oil pumping systems and in measuring weight of tanks, bins, and hoppers were two of the applications described by a chemical engineer, W. H. Bosworth (Ruge-deForest). Other applications are discussed in which remote applications are advantageous and where, in conjunction with recorders and controllers, they are used as primary transducers in automatic systems. The principles of operation of the strain gauge which produces a variable electric signal by changing the diameter of resistance wire and how it is used as an integral component of pressure cells and load cells were described. Pressure cells for highly corrosive conditions and for extreme ranges of pressure are available. For low pressures below 100 lb./sq.in. a bellows and small strain gauge beam is used with a high degree of accuracy. Differential pressures can be measured through a system of attaching two bellows in opposition. Crane scales, which are other units operating on the strain gauge principle, are available in capacities ranging from ½ to 25 tons.

The strain gauge consists of a fine grid of wire (Fig. 4) made of material which translates strain into changes in resistance values directly proportional to the magnitude of the strain. While the actual change in resistance is slight in terms of the overall resistance of the strain gauge it is highly reproducible when measured properly. The grid wire is imbedded in a matrix of paper and cement. Attached to the

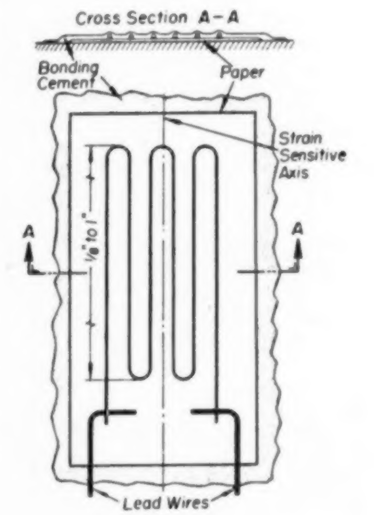


Fig. 4.

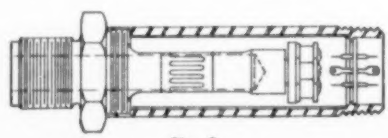


Fig. 5.

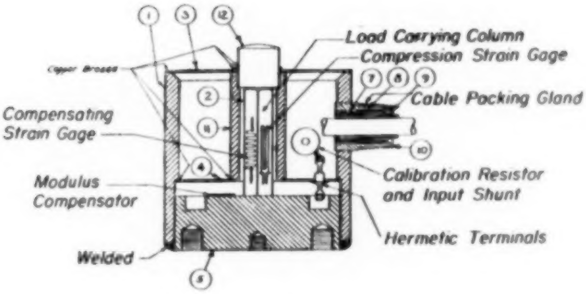


Fig. 6.

grid are substantial lead wires for connection to external circuitry. The device is thus a rigidly mounted grid of wire that will transduce changes in dimension caused by strain into an electrical signal proportional to the amount of strain. The pressure cell and the load cell are units which incorporate strain gauges as the fundamental unit for sensing strain variations.

The Baldwin SR-4 pressure cell consists simply of a hollow tube, with strain gauges bonded to the outside. This is housed in a protective cover as shown (Fig. 5). The unit consists of several strain gauges wired in the form of a wheatstone bridge. The gauges are arranged so that the opposite sides of the wheatstone bridge will increase in resistance. A constant input voltage produces an output proportional to pressure since the hollow tube expands with an increase in pressure. This strain is sensed by the gauges and the bridge is unbalanced and produces an electrical signal proportional to the amount of the strain. The load cell (Fig. 6) is another device based upon the strain gauge principle. The cell consists of a high strength steel column to which the strain gauges are bonded. The gauges are wired in a manner similar to the pressure cells and employ the same basic wheatstone bridge circuit. Similarly the electrical output of the load cells is strictly proportional to load. Capacities of load cells range 50 lb. to 200,000 lb.

Another type of measuring system for measuring pressures below 100 lb./sq.in. is a bellows attached to a small beam having small strain gauges attached to it. As the bellows expands the beam is bent and strained which again results in an output proportional to the pressure on the bellows. Differential pressure can be measured by attaching two bellows in opposition.

One of the most widespread uses of the SR-4 pressure cells is the measurement of pressure in crude oil pumping systems. A typical installation has the cell installed in a remote section of the pipeline with conduit running underground to a central control station. The output of the pressure cell is sent to a single tube electronic amplifier which increases the signal sufficiently to drive an a.c. voltmeter. Where a control function is desired the output of some of these amplifiers can be used to feed into a controller which compares the electrical signal to one which is representative of a desired pressure. This, accordingly operates relay systems for control functions if a change is necessary. In a multiple unit pumping station suction pressure, each pump suction pressure, each pump discharge pressure, and station discharge pressure are measured. The pump discharge and suction pressures control the operation of the individual pumps, while the station suction and discharge pressures are telemetered to the central control station.

Among the outstanding advantages of this type of pressure-measuring-controlling system are the complete absence of mechanical gauges, the remote indicating features, the ability to check the operation of the electronic circuits without the use of calibration deadweights, and the low overall cost.

Electrical auto-batch weight control system for materials

Tank and hopper weighing for the purpose of feeding or storing material is a natural application of the Baldwin's SR-4 load Cell. B. L. Sutton (Gilmore Industries) discussed a set-up for adding accurately three different constituents of a batch process. The advantages of using load cells under tanks and hoppers of odd shapes and out of the way places is pointed out. The adaptability of the strain gauge as a primary transducer for transmitting representative signals to conveniently located automatic recording and control units is also brought to mind. Also the accuracy of the batch system and the simplicity of an electrical weight system are emphasized. Standard instrumentation is used in this system which offers flexibility for complete automation.

A typical application described a 355-lb. hopper which was completely supported by a single SR-4 load cell. The load cell is connected through electrical linkages to material flow controls to each feeder. The tare weight of the hopper which is 100 lb. is adjusted for an initial zero. The hopper is hung free, with stay plates used to restrict side swaying. The electrical system is a modified electronic potentiometer into which is incorporated a servo amplifier, balancing system and an indicating and recording means. It also contains the load measuring circuit and relays and timers necessary for feeder control. Dials are manually preset to determine the amount of each material required. Upon sensing the pre-set amount of material from the first feeder, the flow is stopped, checked and compensated for if necessary. The other constituents are added in the same manner. The system has an accuracy of .25 lb. The manual set points can be adjusted and reset to .1% of scale range.

The application of gravimetric feeders in continuous processing

The uses of gravimetric feeders in solving the problem of metering difficult solid materials were presented by a chemical engineer, Andrew Melnychunk (Omega Machine Co.). Processes using gravimetric feeders of the mechanical type, the pneumatic type and the loss-in-weight type were described. Methods of feeding, weighing, proportioning and controlling were discussed. Some of the difficulties in handling such materials whose bulk densities show extreme variations both while at rest and while in flow were brought out. An accuracy of plus or minus 1% of a given feed rate can be attained with a flow rate of 50 tons per hour. Solids, liquids and slurries of variable densities can be handled with this gravimetric method of determining feed rate.

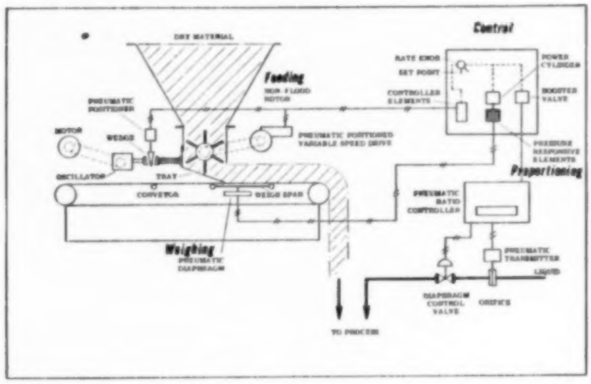
In handling dry materials there is a significant change in bulk density of material at rest and in motion. Laboratory data collected on several materials under static conditions show that an 11 to 60% variation in bulk density can be obtained in a given material. Similar differences can be expected in materials in motion. Field observations indicate there is some relation between the bulk density, the rate of flow in pounds per minute, the orifice size, the particle size, the per cent moisture in the material, the coefficient of friction and the head in the bin above the orifice. With this variation in bulk density, volumetric proportioning becomes difficult if not impossible if high accuracy is desired. Gravimetric feeders offer the highest degree of accuracy for metering solids, liquids and slurries in ingredient feeding.

A description of pneumatic type gravimetric system used in feeding phosphate

rock dust and controlling the flow of acid into a continuous acidulating process used in the fertilizer industry is depicted in the accompanying (Fig. 7). The four essential functions in this feeder are controlling, feeding, weighing and proportioning.

A specially modified pneumatic controller having standard components, including proportional band and reset adjustments, is used in conjunction with an indicator in order to set the desired feed rate. A pneumatic signal determined by this adjustment is connected to the feeding mechanism. The primary feeding of material is by a tightly fitted rubber bladed rotor which is driven by a pneumatically positioned variable speed drive. The rotor effectively contains the finely pulverized aerated material and delivers it to the conveyor belt in a controlled volume proportional to the pneumatic signal received. A secondary feeding or trimming action is contributed by the vibratory tray, whose amplitude of vibration is controlled by a pneumatically positioned rubber wedge. The rubber wedge is operated from the same pneumatic signal received previously. The vibratory tray in addition helps to de-aerate and to maintain a more uniform bulk density of material which is delivered to the weigh belt. The material is carried on a constant speed troughed weigh belt having a pivoted weigh span supported by a pneumatic diaphram. The air pressure required under this diaphram is proportional to the weight of material carried on the belt. This pneumatic signal is then sent to the controller where any deviation from the preset pneumatic pressure is immediately compensated for. The pneumatic signal as received from the weigh span diaphram may also be used to control proportionally the flow of the fluid. The signal is amplified and sent to a liquid pneumatic ratio controller which together with an orifice meter and a diaphram control valve complete the control loop. The capacity of this unit ranges up to 50 tons per hour depending upon the material bulk density with an overall accuracy of plus or minus 1% of a given feed rate. Several of this type of unit are in operation.

Fig. 7.



The use of differential transformers in materials handling

Discrimination between types of fluids using a common pipeline distribution system is being accomplished by continuous specific gravity testing system with a differential transformer as a primary transducer. This is one of the applications of a differential transformer that C. E. Roessler, Jr. (Automatic Temperature Control Co.) gave as an illlustration of the high sensitive capabilities of a system using this new device. The differential transformer is a device for converting change in physical position into a proportional electrical signal. In one application it is attached to the end of a Bourdon tube to sense the motion in the end of the tube caused by hydraulic pressure. In another case it is attached to a torque tube to sense the displacement from equilibrium caused by the variations in the weight of fluid in a constant volume due to specific gravity changes. To measure heavy weights such as a 60 ton chemical storage tank, a combination of differential transformer attached to a Bourdon tube connected to a hydraulic load cell is used. Filling containers with liquid on a production line to a repetitive accuracy of 0.1% along with automatic tare compensation is commonplace. A system using this element, being a transducer, allows remote installation and centralized control.

The differential transformer consists of two primary windings connected in a series-aiding relationship and two secondary windings connected 180 degrees out of phase with each other in a series-bucking relationship. Both the primary and secondary coils are wound together on a single bobbin of ceramic materials. A small iron core when placed within the windings is the controlling factor of the transducer's output signal.

When the primary winding is energized by a small alternating current potential of approximately 3 volts, with the armature in the electrical center of the coil, the flux linkages about each secondary winding are identical, as both secondary windings are electrically balanced. This results in an equal potential being induced into each secondary coil and as the secondary windings are connected in a bucking phase relationship, the voltages induced will cancel each other, resulting in a theoretical zero output. The residual output voltage at this null position is less than .001 volt. When the armature is moved from this neutral position in one direction or the other, a greater signal is induced in one of the secondary windings and a corresponding reduced signal will result in the other secondary winding, due to the shift in the flux field caused by the armature displacement. The difference between the induced potentials in the two secondary windings is the resultant output signal of the transformer. The phase of the output signal is dependent upon the direction of the armature motion. By balance of design between the armature and the flux field, the output signal may be made directly proportional to the amount of armature displacement over a limited operating range. Output voltages of approximately .00025 volts, per volt input on the primary winding for each .001 in. of armature displacement are common on this type of linear displacement transformer. Units are manufactured with output voltages matched to within 0.1% for accumulative applications and for direct replacement of the primary elements.

In the specific gravity testing unit, which is being used by a refinery in its pipeline distribution system, the differential transformer is used to sense displacement of a torque tube which is used as a specific gravity measuring device. The torque tube is a constant volume tube through which a continuous sample of the main pipeline flows. As the specific gravity varies, the weight of the constant volume reservoir tube and the contained liquid varies, so that each incremental change in specific gravity of the fluid forces the reservoir tube to take a new position which is sensed by the differential transformer mounted at the far end of the reservoir tube. The output signal varies directly with the specific gravity.

application of punched cards to chemical process control

R. F. Stevens and J. F. Brady

National Lead Company, St. Louis, Mo.

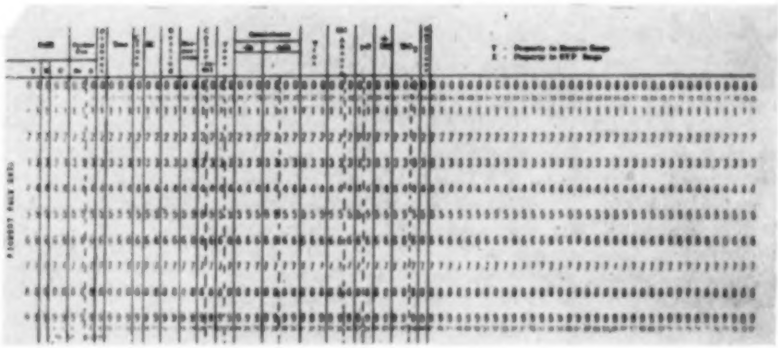


Fig. 2.

As the size and complexity of the chemical plant increases, the magnitude of the control problems becomes a clerical burden. There is a continuous pressure to obtain products of higher quality at lower cost and at a greater rate. The number of chemical analyses made every day in a large chemical plant is astounding, as is the quantity of recorded physical operating data compiled by operating departments and process engineers. At the St. Louis plant of the National Lead Co., Titanium Division, almost 2,000 chemical analyses are made each operating day. Records from plant log sheets and recording instruments are of similar magnitude. These must be summarized and evaluated by trained personnel to determine performance, recoveries, representative quality, and cause-and-effect relationships. This paper describes a system, which has been found to be satisfactory, of employing punched cards and conventional accounting department facilities.

Chemical engineers involved in chemical plant process control are continually searching for ways to reduce the time required to process data, such as the multiple functions of recording, segregating, and converting into tabulated reports various laboratory analyses, plant operating conditions, and production formulae. Mechanization of this process has many desirable features, among which are the utilization of professional manpower for more creative work, the reduction in clerical help required, and a flexibility in making use of data normally obtained in a routine way.

This time saving is accomplished by punching or recording desired information in a digital form into cards of uniform size which by machine can be

1. classified by sorting operations
2. added to other data
3. multiplied by other data
4. divided by or into other data
5. subtracted from other data
6. reproduced
7. listed
8. used for programming

Equipment involved varies from the minimum essential (a punching machine and sorting device) to various combinations of

1. card punching machine
2. card sorting machine
3. punched card interpreter
4. summary punch
5. printing card punch
6. document originating or accounting machine

7. collator
8. calculating punch
9. various storage units

In this work of tabulating, storing, and calculating from operating data, process engineers have had considerable help afforded by various techniques of statistical analysis. These have made it possible to establish more efficient sampling schedules and to estimate better the value and dependability of control tests and analyses. All in all, it has been found that even the minimum amount of data that are necessary for control are more than can conveniently be handled by conventional methods with the use of the pencil, the typewriter, and the desk calculator. The answer to many such problems can be found in the employment of one or several of the punched-card, data-handling systems. These systems, whereby digital information is represented by holes at appropriate locations on the face of the card, make relatively simple rapid recording of basic data into a scheme which will allow mechanical computations at astounding rates of speed. Such systems are also well adapted to many of the statistical techniques used, such as curve fitting by the method of least squares, multiple correlation, significance tests, and analysis of variance.

First Stage of System Development

Data can be recorded into punched cards in a number of ways. At the St. Louis plant of National Lead Co., Titanium Division, the first attempt was to utilize the edge punched cards. Here were recorded daily average chemical analyses at one phase of the process. The product from several rotary kilns was classified as to the kiln used, the per cent titanium dioxide, the calcination temperatures achieved, and several of the quality attributes of the product. An example is shown in Figure 1. These cards are normally sorted by inserting a needle through the stack and allowing those which have been punched on the edge to fall out. By counting the cards from each operation, one can get an average and a frequency distribution with a minimum of effort.

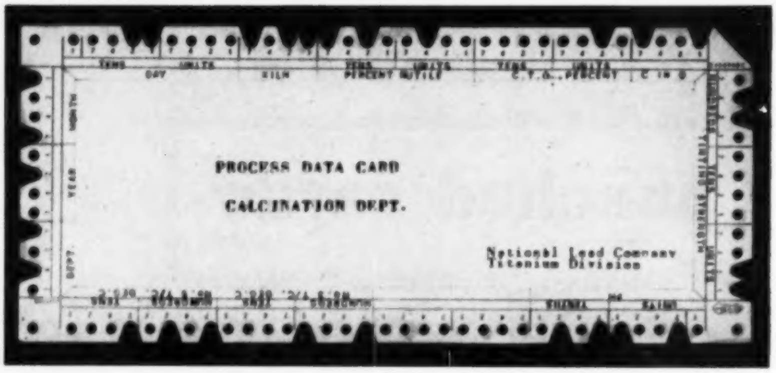


Fig. 1. Rotary kiln operating data on McBee keysort card.

Second Stage

It became readily apparent that this type of data handling would be advantageous in many applications. The accounting department was equipped with some I.B.M. machines, hence the next move was to design an I.B.M. card for the finished product. A diagram of this card is shown in Figure 2. As can be noted, the columns used represent physical dimensions, such as tonnage, pack coding, and the chemical and physical analyses of the lot, and require only 44 of the 80 columns in the card. Since all the information on the individual cards can be printed at a rate of 80 to 100 cards a minute, they can be used to print a daily production report, which is, in effect, a listing of all the material and its chemical and physical analyses on a sheet distributed to the activity centers.

Third Stage

It was decided to use the other 36 columns on the right-hand side of this card for recording process variables for subsequent correlation. Since the process is fairly involved and physical movement through its operations requires something in the order of several days, it was desirable to include as much of this representative process information as possible on the card containing the final product data. Since most process information is expressed in two or three significant figures, this meant that the 36 columns on the card not occupied by final product data would accommodate only about 15 variables as only one punching column may be used for each significant digit.

Fourth Stage

To record a larger amount of information than this, an increase was needed in the storage capacity of the process data side of the card. This is feasible through geometric coding which allows the punching positions from 0 to 9 inclusive to represent numerical values in the geometric progression 1, 2, 4, 8, 16, 32, 64, 128, 256, and 512. (See Figure 3.) Any numerical value between 0 and 1,024 can be represented by punching the combination of positions which add up to that number. Only one combination of numbers from a geometric progression will add up to a given number, and this combination will represent no other number. Hence, any numerical value containing not more than three significant digits can be represented by appropriate punches in a single column of an I.B.M. card. The slide rule shown in Figure 4 has been devised for this purpose, and geometric coding can be determined in a few seconds.

Conversion of a given number to geometric coding is accomplished by finding this number or the closest number below it on the center row of numbers across the slide rule. If punch-

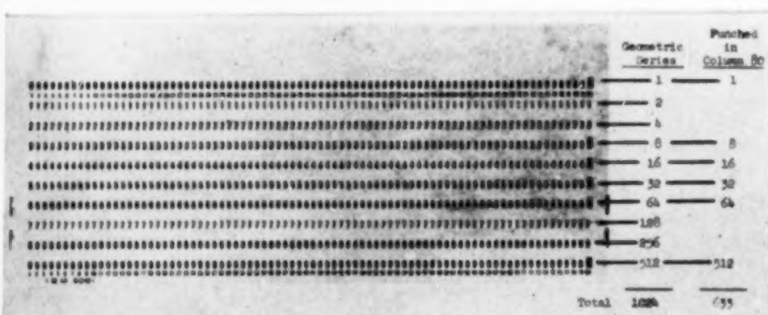


Fig. 3. Application of geometric coding to punching positions on an I.B.M. card.

ing is required in positions numerically higher than 5, these are indicated directly below this number. Alternate reference numbers on the middle row, beginning with 32, receive a punch in the 5 position. To find which of the positions on the card from 0 through 4 should be punched, the 10ths digit of the reference number from the center row is set on the first opening on the left-hand side of the top slide. The units digit of the reference number from the center row is set opposite the arrow (not shown in figure) by the use of the middle slide. By referring to the window on the top slide containing the 10ths digit of the desired number and then referring to the units digit of the desired number beneath this opening, one can find the coding to be punched in the 0 through 4 positions on the card.

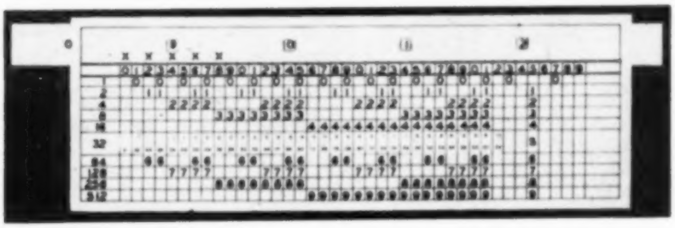


Fig. 4. Slide rule for conversion of numerical values to geometric coding.

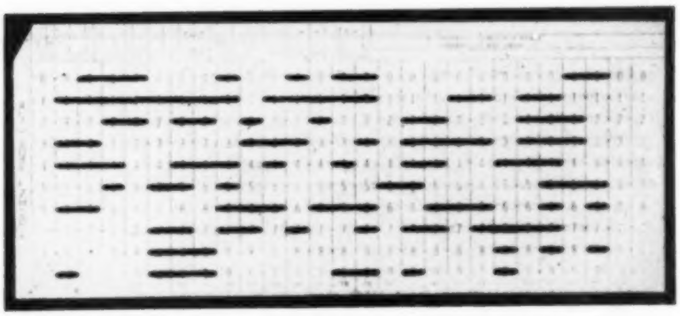


Fig. 5. Mark sensing of geometrically coded data on an I.B.M. card.

Geometric coding, of course, has some disadvantages, one of which is that it is impossible to read data directly from a card. Another disadvantage is that in the use of the normal key punch machine, only one punch can be put in a column; otherwise, one must back-space the machine. In answer to this problem, a "mark sense" type of card is used which is illustrated in Figure 5. Each position to be punched on the card is marked with a special graphite pencil. The cards are then sent through a machine which automatically punches all holes which have been marked with a pencil. These feed through the machine at a rate of 100 a minute.

After the data have been recorded on punched cards, the information is available for a number of purposes. In many industries it is the practice to prepare daily summary sheets of properties and characteristics of products. Such summaries often entail considerable computing, typing, and other clerical work, and result in undesirable lags between the time when the basic data are available and when copies of summaries are distributed for action. With the basic data on punched cards, such summaries can often be run off in a few seconds with a tabulating or accounting machine. At the same time that such summary sheets are being run off on the tabulator, a summary punch may be used to punch automatically the summarized data on to summary cards. Data on cards can be tabulated and added at speeds up to 150 cards a minute, and the data on the printed form produced from the cards is arranged as desired by wiring the control panel on the tabulating machine.

Since cards can be sorted at rates as high as 450 a minute into piles, according to the position punched in a given column, while simultaneously counting the number falling into each pile, it can be seen that accumulated data cards are particularly useful in a rapid preparation of frequency distributions. The vital statistics of a mass of data can be known with considerably more speed by obtaining distributions in this way than with a desk calculator. It has been found that this less burdensome technique encourages the use of statistical methods for process control. Because of the rapid sorting made possible with punched cards, data stored in this manner can be rapidly segregated into desired categories, according to particular periods of time, production equipment employed, process conditions in effect, or according to any other restrictions one might wish to apply to the data.

Example

As an example of this, it was desired to compare the levels of one impurity at various points in the process over a six-month period by using spectrographic data on one element in samples obtained daily over this period. A total of 1,197 cards in the stack contained desired data. It was first necessary to run these cards through the sorter to segregate the cards containing data on samples from the process points which were under consideration. This step required five minutes, and 714 cards were obtained which contained desired data. Next, it was necessary to run these 714 cards through the sorter to separate them into piles representing the process points where the samples were taken. This required three minutes. Thus, in a total of eight minutes, the data had been broken down into the desired categories and were ready to be used for calculations. Next, each of the piles was sorted and counted on each of the three columns assigned to the three digits necessary to express an impurity content.

A digital frequency distribution, as is shown in Figure 6, was obtained. From these distributions, averages and standard deviations of values at each of the process points were calculated by a desk calculator. The averages were then compared with statistical methods. The entire project took about three hours. Based on the advantages obtained in the rapid determination of frequency distributions and the rapid segregation of

data, it was found that the availability of the card-counting sorter and key punch alone, with no more advanced equipment available, justifies the punch coding of a considerable amount of process data.

Advantages

Card-tabulating or accounting machines add considerably to the speed with which statistical information can be obtained. In "progressive digiting," cards are sorted by digital groups and progressive subtotals of these groups are found with the tabulator. The addition of subtotals by the tabulator provides the sum of squares desired. Having this and the accumulated total of the data, one can quickly calculate with slide rule or desk calculator the average and standard deviation. This technique is particularly adaptable in studying differences in results obtained between various processing units by means of the comparison of averages or by variance analysis. It often occurs in the process industries that variation of results obtained is of such magnitude that to establish definitely the differences gained on various processing units, much data have to be subjected to analysis of variance. The availability of a means for rapid calculation of such analyses encourages the use of statistical tools for the examination of such differences rather than the expedient of guess work.

Another advantage in storing data on punched cards is the availability for rapid examination of relationships which may exist between process variables and final product properties. Such relationships can be studied—one process variable at a time—with the simple correlation technique, or the combined effect of several process variables upon a final product property may be investigated by the method of multiple regression. These statistical methods may be employed to determine the degree of certainty with which one may say that such relationships exist and to determine the amount of variability of the final product property corresponding to the given process variable.

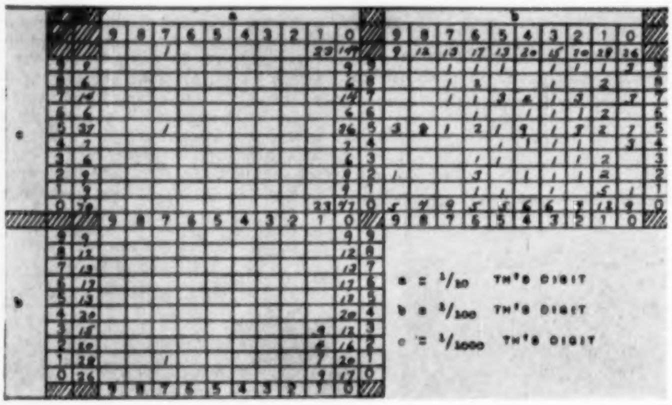


Fig. 6. Digital frequency distribution for impurity levels at sampling point No. 3 (127 samples).

A multiple regression calculation was carried out with spectrographic data cards. This calculation involved two of the properties of the final product as dependent variables. With cards representing 112 samples from one particular process point these properties were correlated against eight independent variables. Six of these variables were elements determined spectrographically, and the other two were concentrations of compounds determined by X-ray diffraction analysis. This eight-independent-variable multiple regression required ten simple summations, ten sums of squares, and forty-four sums of cross products. All these quantities were obtained with a card-counting sorter by means of digital frequency distributions, and a period of 40 hr. was required to segregate the data and secure this basic information. With the method of progressive digiting a tabulator would have cut this time down to a few hours. The eight simultaneous equations which required solution for calculating regression coefficients were solved by the Doolittle Method, which took about five days. Again, the time required could have been cut to a fraction of this by the use of a tabulator or a calculating card punch. With multi-unit equipment such as I.B.M. 701 or the Remington Rand Univac, solution of these equations could be accomplished in a matter of minutes.

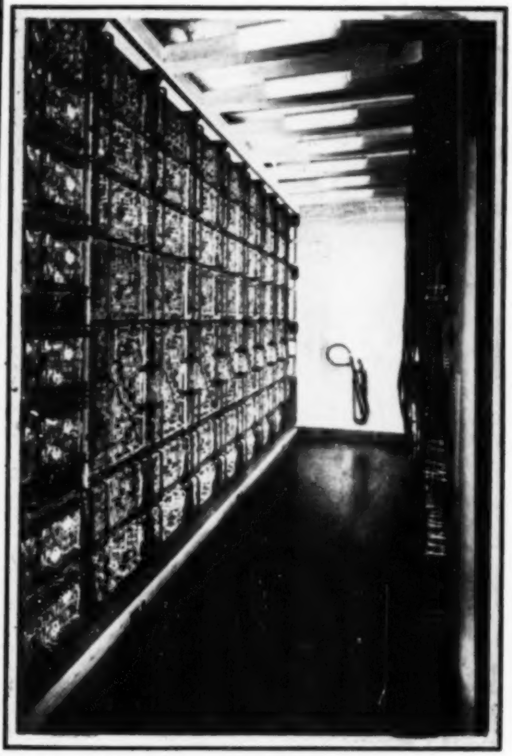
The regression coefficients obtained and their significance are shown in Figure 7. Here independent variable D was the only variable which indicated a significant correlation with dependent variable 1 showing an approximate .03 decrease per one unit increase of D. The variance of dependent variable 1 attributable to D was 9.6% of the total. On the other hand, independent variable E is the only variable for which a significant correlation was indicated in the correlation of dependent variable 2. A 1.1 decrease in dependent variable 2 was shown per one unit increase in E, and 4.3% of the variable 2 variance was attributable to variations in E. It should be pointed out that the nonsignificance of the correlation of the other independent variables does not necessarily mean that no correlation exists. There is the possibility that, because of lack of sufficient variability of the independent variables or because of excess variability of the dependent variables due to undetermined causes, the data might be inadequate to show a correlation, even though one exists.

INDEPENDENT VARIABLES	REGRESSION OF DEPENDENT VARIABLE 1.		REGRESSION OF DEPENDENT VARIABLE 2.	
	COEFFICIENT	SIGNIFICANCE	COEFFICIENT	SIGNIFICANCE
A	0.0094	< 90%	-0.216	< 90%
B	-0.0021	< 90%	0.247	< 90%
C	2.38	> 90%	279.3	< 90%
D	-0.0256	> 99% < 99.9%	0.087	< 90%
E	0.0217	< 90%	-1.148	> 95% < 98%
F	0.397	< 90%	15.158	< 90%
G	-12.998	< 90%	512.2	< 90%
H	0.383	< 90%	-14.34	< 90%

Fig. 7. Multiple regression coefficients and their significances for eight independent variables correlated with two dependent variables.

After completion of the initial stages of adapting punched-card methods to a number of process control problems, one can state that what appeared to be a rather complicated procedure at first has resulted in an actual simplification of a number of duties and problems.

Presented at A.I.Ch.E. Washington, D. C., meeting.



One bay of calculating equipment. Units are interchangeable for quick servicing.

use of computers in kinetic calculations

Gas-Phase Tubular Reactor Kinetics Involving Differential Fouling of Heat-Transfer Surface

R. E. Gee, W. H. Linton, Jr., R. E. Maier, and J. W. Raines

E. I. du Pont de Nemours and Company, Wilmington, Delaware

The purpose of this paper is to show how the general practitioner in chemical engineering can make more use of applied kinetics in industrial work. The material is not aimed primarily at the kinetics specialist, although he might find the approach useful. In most industrial work the use of sound applied kinetics has been limited too frequently by the mathematical complexities which force the engineer to make many undesirable simplifying assumptions. This means that the practicing engineer does not make sufficient use of the fundamental academic work in kinetics, particularly in combining concepts from several idealized systems with his admittedly complex, practical system. The authors hope by the example given here to show that large computers, which are now available, permit the general practitioner to make more use of reaction kinetics. A companion paper by J. A. Beutler on programming for such computation will appear in a later issue.

A process study of an industrial reactor led to kinetic relationships too difficult mathematically for solution by ordinary desk methods. The system studied was a homogeneous gas-phase reaction occurring in a tubular reaction system (pipeline reactor) in which part of the heat of reaction was transferred to the surroundings. It was necessary to derive special relationships to take into account the change in heat transfer caused by fouling of the tube wall. The variation in heat-transfer coefficient with position in the tube and on-stream time together with the nonadiabatic, nonisothermal conditions in the reactor led to simultaneous, nonlinear, partial differential equations which required machine solution. For this work the Whirlwind I computer at Massachusetts Institute of Technology was used. Results show how a large computer can serve as a pilot plant.

Extensive industrial application of mathematics in chemical-engineering work is frequently limited by the need for making too many assumptions. In many cases the operation in question can be described adequately by differential or algebraic equations, but the equations are too complicated to solve on a practical basis. Recourse is then made to simplifying assumptions. For example, equilibrium may be assumed when it is not justified, or secondary reaction-rate effects may be neglected. In academic work the experimental system is carefully chosen and controlled so that the idealizing assumptions necessary are fulfilled. In this way the results of the experiments can provide the best test of that part of the theory which fits the case chosen. In applied research, on the other hand, the system cannot be chosen with such freedom, and the desired simplifying assumptions cannot be made. As a result, most industrial problems are approached on an empirical basis.

In the past five years, however, electronic computers have been developing into a practical tool for solving complex mathematical relationships without the necessity for making the simplifying assumptions previously found necessary. This development potentially bridges the gap between the academic approach and the applied industrial problem; it means

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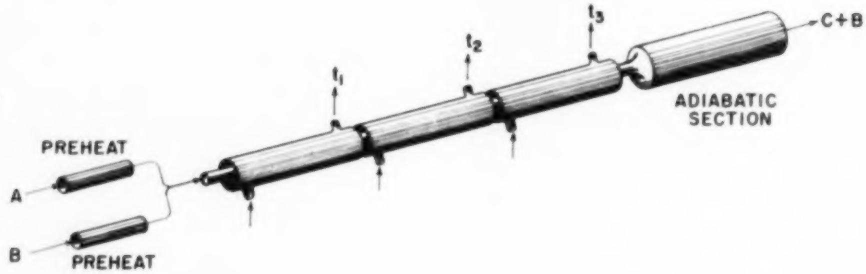
Fig. 1. Schematic drawing of the reactor system.



that use can be made of the theory built up from idealized systems, and that the elements can be combined into a practical, although complex, description of the problem. To cite some examples, the work of Rose and Johnson (3) points out that computer calculations make it possible to take into account fourteen different nonidealities and irregularities usually neglected in distillation calculations even though they may occur simultaneously during a single distillation. In another instance in a recent paper by Perry and Pigford (2), calculations by machine were made for new cases of absorption combined with chemical reaction. Their results indicated that the height of a transfer unit was a function of the equilibrium constant, and that the limiting cases previously calculated by no means covered the range of practical interest. Rose et al. (4) review other recent work in this field.

Process Under Consideration

Under consideration is a noncatalytic, homogeneous, gas-phase reaction that takes place in a nonadiabatic, nonisothermal tubular reactor, shown schematically in Figure 1. The reactants will be designated *A* and *B* and the product of this reaction *C*. The two gaseous reactants are independently preheated to the desired temperature and introduced into the reactor at the desired pressure. There is always an excess of reactant *B*. After mixing, the gases pass immediately into the tubular reactor which consists of a long section of jacketed pipe with three separate cooling sections for heat removal. Temperatures of the three sections are individually and automatically controlled. An expanded section of pipe is added at the end of the reactor in which the remaining *A* is completely reacted under adiabatic conditions. The gaseous product, plus unreacted *B*, is sent through a product recovery system and the excess *B* is recycled. The initial ratio of *B* to *A* and the coolant temperature in the three jacketed sections are continually measured and controlled. The gas temperature in the adiabatic section and at increments along the reactor is measured and recorded. After the reactor has been in operation a short time, the inside of the tube wall begins to foul with a cokelike byproduct or degradation product from the reaction. It is necessary to shut down the reactor after extended operation and physically bore out the inside of the reactor tubes.

Mathematical Description of Process

The equations used are typical for tubular reactor systems (with the exception of Equation 4 and are given in Table 1 along with a listing of the important assumptions used in the derivation.* By solving only Equations 1, 2, and 3, one can obtain all the effects of the process variables on conditions at every point in the reactor and on production rate; but this is true only if the heat-transfer coefficient is a constant. In many cases, as in the process under consideration, by-product reactions result in fouling of the reactor walls. The heat-transfer coefficient for those systems changes with time onstream and, as a result, the delicate balance between the reaction heat absorbed by the flowing gas stream and the heat transmitted through the reactor walls is being continually upset. As fouling increases, the reactant feed rate must

* Detailed derivation on file at the American Documentation Institute, Washington, D. C. (see footnote, page 497).

Table 1.—Process Equations

Type of Relationship	Starting Equation	Final Form of Equation	Important Assumptions Beyond Starting Equations
1. Kinetic	$-\frac{1}{V}\frac{dx}{d\theta} = K\left(\frac{x}{V}\right)\left(\frac{B}{V}\right)$	$\frac{\partial z}{\partial L} = \frac{K(1-z)}{4x_o}\left[\frac{r-z}{(r+1-z)^2}\right]\left[\frac{pD}{R(273+t)}\right]^2$	1. (a) Perfect gas laws (b) Side reactions are small and unaffected by process conditions (c) All radial concentration gradients negligible (Reactor L/D is high)
2. Pressure drop	$-\frac{dp}{dL} = \frac{2fG^2}{g_c \rho D}$	$-\frac{\partial p}{\partial L} = \frac{2fM_{av}R(t+273)\,[x_o(r+1-z)]^2}{g_c\left(\frac{\pi}{4}\right)^2 D^5 p}$	2. Average molecular weight may be used
3. Heat balance	$dQ = wc_p dt + U\pi D(t-t')dL$	$\frac{\partial t}{\partial L} = \frac{x_o \Delta H}{wc_p}\frac{\partial z}{\partial L} - \frac{U\pi D(t-t')}{wc_p}$	3. Average c_p and ΔH may be used
4. Heat transfer (fouling)	(a) $\frac{dF}{d\phi} = k'x^n$ (b) $1/U = 1/h_c + F/k$	$-\frac{1}{U^2}\frac{\partial U}{\partial \phi} = ax_o{}^n(1-z)^n e^{E'/R(273+t)}$	4. Average h_c and k may be used

be progressively reduced to prevent excessive temperatures.

In general, the correlation of the effect of process conditions on fouling will be unique to the reaction considered. In the industrial reaction discussed here it was observed that most fouling occurred at the hottest parts of the tubular reactor, and chemical analyses showed high concentrations of A in the coke-like deposit near the inlet of the reactor where the concentration of A in the process stream was high. Therefore, Equation 4a is drawn up to state that coke is deposited at a rate fixed by temperature and local flow rate of A. Equation 4b states that the resistance to heat transfer is the sum of the standard convective resistance and the resistance of the coke deposit.

It is apparent that Equation 4 makes the entire set of equations partial differential equations. That is, there are two independent variables: length down the tube (L) and time on stream (ϕ).

The constants in these process equations were obtained from laboratory studies, from the literature, and from process data. The correlation for reaction-rate constant is shown in Figure 2.

These equations give the complete mathematical description for the process. For practical application and use of these equations involving only hand computations many simplifying assumptions would be required. These might be (1) assume no change in the number of moles in the process stream along the reactor length, (2) assume no effect of pressure drop through the reactor, with an average pressure, (3) assume that satisfactory conclusions could be drawn from solutions obtained for zero on-stream time and qualitative use of the heat-transfer fouling relationship. The only method of determining whether any of these simplifying assumptions would actually lead to serious errors is by hand solution of the equations. The equations were solved by numerical integration for many cases to check the assumptions and the agreement with actual experimental data where available. It was found necessary to use the complete mathematical description and to avoid these assumptions.

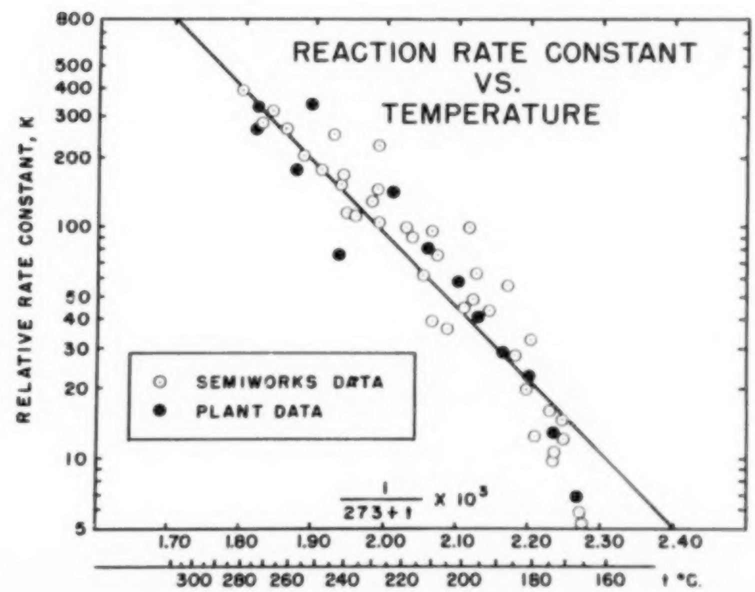


Fig. 2. Reaction rate constant as a function of temperature.

Computer Solution

It is apparent that a machine solution of the process equations is needed so that the simplifying assumptions can be kept to a minimum. The equations were solved on the M.I.T. Whirlwind computer, a general purpose, electronic digital computer, and among the fastest computers in the world. The steps required for obtaining solutions with the aid of the computer are:

1. Reduce the differential equations to difference equations and fix all boundary conditions and control limits imposed by physical considerations

2. Construct a detailed mathematical flow diagram which shows the sequence of operations to be taken in solving equations

3. Convert the sequence of operations into a series of actual machine instructions (Computer Program)

4. Prepare punched paper tapes containing the machine program in proper form, and test operation

5. Operate the computer and obtain results in the desired output form: typewritten data, photographs of oscilloscope plots of important variables.

The above steps are discussed in detail in "Programming of Kinetic Calculations for Automatic Computation," a paper by J. A. Beutler (*1*).

Examples of the instructions and restrictions used in the computer solution of the problem are:

(1) Solution will start at an initial feed rate (x_o) of A equal to 25

(2) If the temperature reaches a predetermined maximum value at any point in the tubular reactor or adiabatic section, that profile will automatically be repeated using one unit less A feed

(3) Every time a successful temperature (t) and conversion (z) profile is obtained, another is automatically started using the same x_o but with a value of ϕ (on-stream time) increased by predetermined increment

(4) A run will be automatically terminated when $x_o = 10$

(5) A photograph will automatically be taken of both the successful and unsuccessful conversion (z) and temperature (t) profiles at selected values of ϕ

(6) Values of the heat-transfer coefficient U will be automatically typewritten for a number of values of L after each successful profile

(7) Every time a gas temperature is computed, an automatic check will be made to determine if that temperature is below the coolant temperature at that point. If the gas temperature is lower than the jacket temperature, the value of $U = 10$ will be used to correspond approximately to heating by natural convection.

Among the thousand-odd instructions given to the computer, there are some which provide for the display and recording of three main variables (temperature, conversion, and heat-transfer coefficient).

The gas temperature at intervals along the reactor length was plotted on an oscilloscope, the individual points being close enough to form in effect a continuous curve. A photograph was taken (time exposure) of a profile at selected values of ϕ. At the start of each new profile, the film in the camera was automatically changed and the picture was indexed. The points in the adiabatic section of the reactor usually appeared somewhat scattered because of the numerical integration method. The conversion of A was calculated and plotted vs. reactor length at regular intervals on the same oscilloscope graph as the temperature. After each successful profile, the heat-transfer coefficient values to be used in the next profile calculation were automatically typewritten.

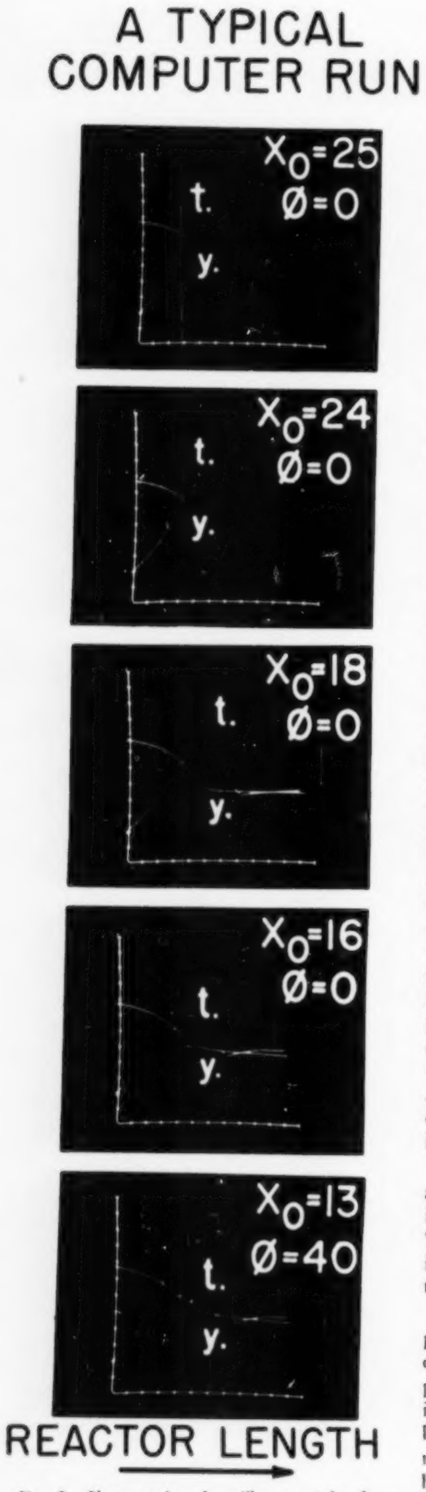


Fig. 3. Photographs of oscilloscope tube face during operation of the computer.

Results of Calculations on Whirlwind Computer

A. TYPICAL RUN

Fifty sets of operating conditions, representing all combinations of variables in the range of practical interest, were chosen and the appropriate punch tapes containing this information were prepared. Figure 3 shows the temperature and conversion profile during one of the runs of these fifty sets. The picture for $x_o = 25$ is a good example of what happens when the feed rate of A is too high: the temperature, t, reaches the limit value a short way through the reactor. The machine stops calculating this profile, reduces the feed rate to $x_o = 24$, and begins calculating a new profile. As the photograph shows, this also is too much A and the A feed rate is again reduced. In this run such a cycle was repeated until $x_o = 18$. At this feed rate the limit was not reached in the tubular section, and a hot spot resulted instead of a runaway reaction. It should be noted that the "conversion" curve dropped rapidly in the hot spot, indicating that most of the reaction had been occurring there. Incidentally, the conversion curve does not drop to the x axis at complete conversion because of the scale factors which were found necessary. For this profile (at $x_o = 18$, $\phi = 0$), the temperature limit was exceeded in the adiabatic section because of insufficient conversion in the tubular section. This is not readily seen from the photograph for two reasons: first there are only a few points calculated along the profile in the adiabatic section because of the programming method, and second in this case the limit was exceeded quickly and the last point was above the area of display on the oscilloscope. The A feed rate was therefore reduced successively to $x_o = 16$, and at this value a profile was calculated which satisfied all limits imposed.

The break in the temperature curve about 60% along the profile for $x_o = 16$ is the start of the third jacket section. This illustrates the effect of a change in the cooling temperature along the tube wall.

After calculation of the successful profile for $x_o = 16$ at $\phi = 0$, the machine immediately began calculating a profile for $x_o = 16$ at $\phi = 10$, taking into account the fouling which occurred between $\phi = 0$ and $\phi = 10$. With the reduced heat-transfer coefficient caused by this fouling, profiles were calculated as at zero time until a successful one was obtained. This continued at $\phi = 10$, 20, 30, etc. A typical result is shown in Figure 3 (bottom) for $\phi = 40$ and a feed rate which has been reduced to $x_o = 13$. The run was automatically terminated when $x_o = 10$.

B. GENERAL RESULTS

Since the primary interest in this study was the productivity of the plant reactors, the most direct measure of the effectiveness of a particular set of reaction variables should be the production. Production of course is directly proportional to the feed rate of the limiting reactant, reactant A. In addition to being able to compare the production indicated by the computer with actual plant production, it was possible to learn from the computer how best to operate the reactor.

It became apparent during the work that the temperature profile provided an excellent clue to the performance of the run, and gradually a picture was built up of the most desirable profile shape. The method of analysis of the data, therefore, was to go over each run and to examine the temperature profile in detail. It was found that productivity was linked to the hot-spot position. When the hot spot was in the upstream part of the reactor during the early part of the run, the run life was limited and average production therefore decreased. The effect of the variables on the temperature profile in general and the hot spot in particular were determined. For example, it was shown that small changes in the first section jacket temperature had marked effects on ultimate run lengths and hence production. Some of these temperature profile differences are shown in Figure 4.

The same type of study was made on the effect of changes in the other two jacket temperatures, inlet gas temperature, and pressure. Production increases also were estimated for changes in reactor operating conditions.

In a consideration of the checking and verification of the mathematical model with actual plant operation, three methods of checking computer results were used:

(1) comparison of the method of operation and control of the computer runs with actual plant experience

(2) comparison of changes in temperature profiles with changing operating conditions for computer and actual plant

(3) comparison of actual production increases obtained at the plant with those obtained on the computer when certain operating variables were changed.

First the experience comparison: one of the experienced men from the plant operated the computer for certain of

the computer runs and concluded his work with the remark that the response to changes in the operation of the computer was the same in almost every respect as in the operation of the actual plant. He said that his plant experience was directly translatable to techniques for operation or manipulation of the computer. Though somewhat novel, this can be regarded as an important check of the computer results; in fact, in all computer-simulation studies carried out in these laboratories, the engineer or chemist familiar with the process actually operates the computer.

The second comparison is with temperature profiles. The position of the peak in the temperature profile and the way it moved with time was checked against measured temperature profile peaks and their shifts in the actual operating unit. The effects of changing certain variables on the computer resulted in the same changes of temperature profile at the plant. In a way this check is not surprising since the good rate-constant correlation of Figure 2 made this practically certain. In fact, the rate-constant correlation is perhaps more desirable as a scientific check.

The third method of checking computer results was through production changes. The indicated conditions for increased production from the computer results were checked in actual plant operation. One computer run was made with conditions which approximately agreed with a plant reference run. Production rates for different conditions on the computer were determined and compared with the reference run. Figure 5 is an example of such a comparison. The initial flow rate of the limiting reactant A, (x_o) is plotted against the time on-stream (ϕ), both on a logarithmic scale. This type of plot was used to correlate plant and computer data and gave a straight line in all runs. These two runs were made on the computer with all conditions constant except the 7° C. change in first section jacket temperature. Points for the 167° C. run fall considerably above those for the 174° C. run, indicating a higher production throughout. By a proper integration of the production over the total on-stream time, it was calculated that the average production in the 167° C. run is 20 to 25% greater than that in the 174° C. run. The sole difference to which this production increase is attributed is the reduced first section jacket temperature with a consequent improvement in the shape of the temperature profile. The plant unit was changed to approximately the conditions the computer used and the observed production increase was 25%, which agrees well with the predicted value (Table 2).

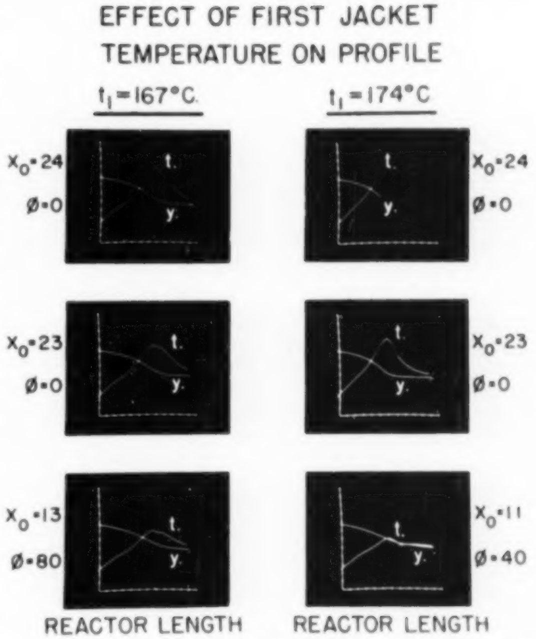


Fig. 4. Photographs of oscilloscope tube face during computer operation. Note the differences in hot-spot position caused by the change in reactor conditions. Note the breaks in the temperature curve caused by changes in the three jacket temperatures. The only difference in process conditions in these two runs is the change in t_1 (first jacket temperature).

process design

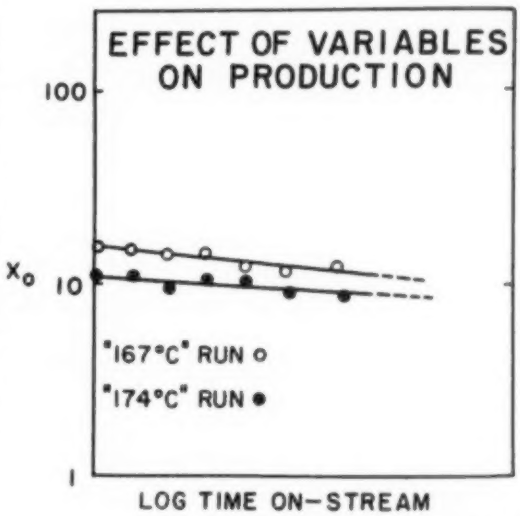


Fig. 5. Production rate (X_o) vs. time "on-stream" comparing computer runs which were identical except for the indicated change in first section jacket temperature (t_1).

Table 2.—Comparison of Production Rates for Computer Runs and Plant Runs

Conditions	Computer Reference Run	Computer Improved	Plant Reference Run	Plant Improved
Inlet temperature	150	150	150	150
1st jacket temperature	174	167	177	167
2nd jacket temperature	177	177	177	174
3rd jacket temperature	198	198	198	198
Relative production rate	100	120–125	100	125

Conclusions

A. THE PROCESS

Two practical results were achieved; the more important was the improved method of operating the plant reactor. The operators now are closely watching the temperature profiles throughout the run, and know what operating variables should be used to change to the desired profile shape. This has resulted in improved efficiency of operation and intangible production increases. Of a more tangible nature is the 25% increase in production from a simple change in operating conditions. No doubt the plant personnel would have arrived at these improved conditions sooner or later—the computer study greatly facilitated getting there, pointed out how far to go, and indicated the troubles that might be encountered on the way.

B. USE OF COMPUTERS

First a substantial amount of time was saved through use of the computer. Each point on a temperature profile required about 0.7 sec. for calculation on the machine. A complete temperature and conversion profile required about 60 sec. An entire typical run required 30 min. of computer time. The program as a whole used 30 hr. of machine time for fifty runs (fifty sets of conditions) plus another 12 hr. of machine time for programming and preliminary runs. The estimated time for hand solution of the same work is twenty years for one man. The estimated time for an actual semi-works duplication of these runs is several years.

Second the computer as finally set up actually was a simulated pilot plant, *i.e.*, the conditions imposed and results obtained were of the kind that chemical engineers use in process work, rather than in obscure mathematical quantities. Furthermore, conditions could be varied over tremendous ranges, even into extremely undesirable combinations. In fact, the reactor was "blown up" many times with wrong combinations of conditions—it was convenient to blow up the reactor without having to rebuild equipment each time.

Finally, one unexpected benefit resulted from this study—the dramatic demonstrating power of a large computer used as a process pilot plant. It was unusually clearly shown that practical plant results can be obtained from the mathematical description of a process with a fundamental chemical engineering analysis. Furthermore, this was done in terms clear and helpful to the widest range of people involved in the problem. In addition, the computer results showed clearly the inner workings of the process as a complex combination of basic chemical and physical transformations.

Acknowledgment

Acknowledgment and appreciation are expressed here to the M.I.T. Whirlwind computer personnel who assisted in solving this problem. The authors also want to acknowledge the help given in numerical computations and analysis by Ann Sheldon of the Du Pont Polychemicals Research Laboratory and by J. A. Beutler and the computation staff of the Du Pont Engineering Research Laboratory.

Notation

a = constant
B = flow rate of B at any point in the reactor, moles/unit time
c_p = average specific heat of products and reactants throughout reactor length
D = inside diameter of tubular reactor
E = activation energy for main reaction
E' = pseudoactivation energy for the fouling reaction
F = thickness of coke deposit on reactor walls
f = average friction factor for turbulent gas flow through reactor, dimensionless
G = average mass velocity of gas flowing through reactor
g_c = gravitational constant
ΔH = heat of main reaction
h_c = heat-transfer coefficient (by convection) across gas film on inside of tubular reactor
K = reaction-rate constant for main reaction
k' = a constant; pseudorate constant for fouling reaction
k = average thermal conductivity of the coke deposit on reactor walls
L = reactor length
M_{av} = average molecular weight of flowing gas stream in reactor
n = a constant
p = pressure of gas stream at any point in reactor
Q = heat evolved at any point in reactor from reaction, per unit time
R = gas constant
r = mole ratio of B to A in the feed, dimensionless
t = temperature of gas stream at any point in tubular reactor, ° C.
t' = temperature of coolant in jackets, ° C.
U = heat-transfer coefficient (over-all) between flowing gases and jacket water
V = total volumetric flow rate at any point in reactor
x = flow rate of A at any point in reactor, moles/unit time
x_o = initial A feed rate, moles/unit time
y = fraction of original A unreacted, dimensionless
z = fraction of original A reacted, dimensionless
θ = contact time
ρ = average density of flowing gases in reactor
ϕ = on-stream time; length of time reactor has been in operation

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Discussion

Anonymous: You mentioned a 25% improvement in production calculated by the machine as confirmed by actual plant operation. At which point do you become skeptical of an indicated improvement based on machine calculations? That is, if you get a 2% improvement based on machine calculation, do you believe you'll get this in the plant?

W. H. Linton, Jr.: I think if we had come up with a 2% improvement with one set of variables, we wouldn't be skeptical as to whether that was caused by the variables in question, but would be skeptical on our ability to control the conditions to get it. Perhaps 5% or so would begin to be practical.

R. E. Gee: One of the advantages of using computers of this type is that the change that you note as a result of a computer run is a change caused by that one variable being changed on the computer. The fact that we got 25% increase in the plant and that the computer indicated we would get 25% increase might be somewhat fortuitous, but we did estimate that quite accurately—we said just how far to go with that particular variable, at what point we might run into other troubles. And so we gave this to the plant people to use as a basis of change. We would not, of course, say to do this just because the computer says so. We use it as a basis to be able to make changes more wisely.

R. R. Hughes (Shell Development Co., Emeryville, Calif.): There are still some assumptions present, particularly the assumption that there was uniformity across a given cross section. How much error was introduced by that and did you make any attempt to allow for that?

W. H. Linton, Jr.: As far as radial variations in any of the quantities is concerned, these were assumed unimportant because of the high L/D in the system. The correlation of rate constants agrees with this.

Presented at A.I.Ch.E. Washington, D. C., meeting.

the problem of liquid entrainment

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The existence of liquid entrainment is certainly not "news" to chemical engineers. Recently interest in the varied problems presented by liquid carry-over has increased, leading to study of the methods and means by which it can be controlled (*1*). The word *controlled* is used advisedly, because entrainment cannot be prevented by any means now known. The rapid growth of processing industries, the increasing complexity of operations, and the economic necessity for increased on-grade production, from both existing equipment and new plants, have focused interest on entrainment.

This paper attempts to define entrainment and discuss its effects on plant operation, product quality, equipment design, and even on public relations.

What Is Meant By Entrainment

Whenever a gas is generated in or is passed through a liquid or a spray, complete separation of the two phases never results. The gas always carries with it varying quantities of the liquid in the form of small droplets. These entrained droplets—a type of liquid particle suspension—are so small in size that they do not fall out of the normal gas flow by gravity. The liquid is therefore carried on to the next processing operation or escapes through the exhaust stack into the atmosphere.

Particle sizes naturally vary not only with the nature and velocity of the gas, but with the chemical and physical characteristics of the liquid. In some cases these droplets are sub-micron in size and can float on still air like smoke. In other operations they are so large that individual droplets are visible to the human eye. The amount or volume of this liquid carry-over also varies. In some instances small particles of solid matter may be carried along in the entrainment. In others the composition of the liquid is such that solids may be created by the operating conditions and temperatures.

All these factors should be considered in determining the method of entrainment removal that should give the most effective and economical results for any given operation.

Entrainment Control

Why be bothered about entrainment? may seem a perfectly logical question, but the answer can be given only after honest determination of the effects on plant operations and how conditions can be improved by control of entrainment.

Liquid carry-over can do only two things; it can go out the stack and be lost, or it can be carried on to the next step in your processing operations. If the entrainment is lost in the effluent gases, it should not be too difficult a matter to determine how much goes up the stack, what would be its value if it were to be recovered, and how much spending is justified to achieve this recovery over a given period of time. In this connection, however, the reduction of air pollution and of working hazards because of this lost entrainment is becoming a more and more serious consideration to many plants depending both on conditions in the immediate vicinity and on the corrosive or noxious effects of the entrainment itself.

When the entrainment is carried on to further processing operations, other questions are involved:

What harmful effects does this liquid have on subsequent operations?

Will its removal increase product purity?

Will its removal increase on-grade production?

Can this liquid be returned and processed further to increase over-all production?

If the liquid were not present, could as good a product, or perhaps a better one, be made with lower grade feed stock?

Would the absence of this entrainment reduce corrosion and lower costs for equipment maintenance?

If there were no liquid carry-over, would not smaller and less expensive vessels produce equivalent volume and quality?

If the answer to any appreciable number of these questions is "No," then entrainment control is not necessary. But in a free and competitive society where the ratio of dollars spent for plants and plant operation to dollar sales is the basic governing factor, entrainment problems cannot long be lightly dismissed.

Selection of an Entrainment Separator

No one without weighing all factors involved in any entrainment removal can honestly give an answer to the question, "What is the ideal entrainment separator?" Long ago the ancient Greeks found that there was no such thing as a panacea for all bodily ills, because all bodily ills are not alike. So today no one method of entrainment separation is a panacea for all liquid carry-over problems. The "symptoms" of a particular entrainment situation must be studied and evaluated. Then, and only then, can one begin to decide on the "cure." Just as a doctor consults with other doctors on puzzling cases, so you can consult with manufacturers and users of the various methods of entrainment removal and equipment.

There are certain broad specifications which good operating, engineering, and management experience would indicate to be basic in the selection of this equipment.

1. **The method or equipment must be able to handle the type and quantity of entrainment present in your processing operation.**
2. **It should have high removal efficiency and maintain this efficiency at least through normal operating cycles.**
3. **It should, if possible, be self-cleaning at least through expected runs.**
4. **It should be low in initial costs installed and low in costs for operation and maintenance.**

5. It should maintain its efficiency through a wide range of operating velocities to permit increasing or lowering input.
6. It should be as small and compact as consistent with performance, and installation should require only a minimum of special construction.
7. It should be automatic in action and require little, if any, servicing between turnarounds or shut-down periods.
8. It should require little, if any, power and should operate with a minimum of pressure drop.
9. It should provide for simple and effective recovery of the liquid removed and prevent re-entrainment.
10. It should be adaptable to existing vessels as well as to new equipment.

In the last analysis the decision will be based on sound chemical engineering practice and on economics. The results to be achieved must govern the amount of expenditure. "You get what you pay for" is just as true in the processing industries as it is at the corner store.

Conclusion

This paper was not conceived as a new presentation of what is already on record, but is rather the result of my personal observations over several years of contact with chemical and process engineers promoting and selling entrainment separators.

Entrainment, though it is an inevitable part of practically any processing operation, is apparently not generally recognized as a curable condition. It is not limited to any particular piece or type of processing equipment. It may, and often does, occur in several places or stages within a single vessel.

Entrainment seems to have been considered an unavoidable evil, like the common cold. But the experience of many customers shows that entrainment *can* be cured—with efficiency, with economy, and with benefit to many process operations.

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simultaneous heat and mass transfer in a diffusion-controlled chemical reaction

PART II | studies in a packed bed

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Part I of this paper considered the case in which the reacting mixture is passed through a cylindrical tube, the wall of which is an active catalyst. The present Part II discusses a system in which the vapors are passed through a bed of catalytic spheres.

The mass transfer rates were found to have an average deviation of 5.8% from the equation: $j_D = 0.667(N_{Re,f})^{-0.34}$, which predicts values of j_D slightly lower than other mass transfer correlations. The difference is attributed to the smoothness of the sphere packing used here. Heat transfer rates between the bulk stream and catalyst surface gave values having an average deviation of 6.4% from the expression: $j_H = 0.992(N_{Re,f})^{-0.34}$, which agrees well with previous data. Values of j_H/j_D gave an average deviation of 5.5% from 1.37, a value slightly higher than the usually assumed value of 1.0.

The phenomenon of hot spots in a packed bed is examined from the viewpoint of simultaneous mass and heat transfer rates.

Previous studies on mass transfer in packed beds in the range of Reynolds numbers considered here have been obtained with four different types of physical systems, all of which differed from the present one in that none involved high temperature gradients between solid and fluid, or chemical reaction: (1) evaporation of volatile liquids from porous particles into gases

For Tables 1 and 2 order document 4317 from A.D.I. Auxiliary Publications Photoduplication Service, Library of Congress, Washington 25, D. C., remitting $1.75 for microfilm or $2.50 for photoprints. This document also includes material supplementary to Part I.

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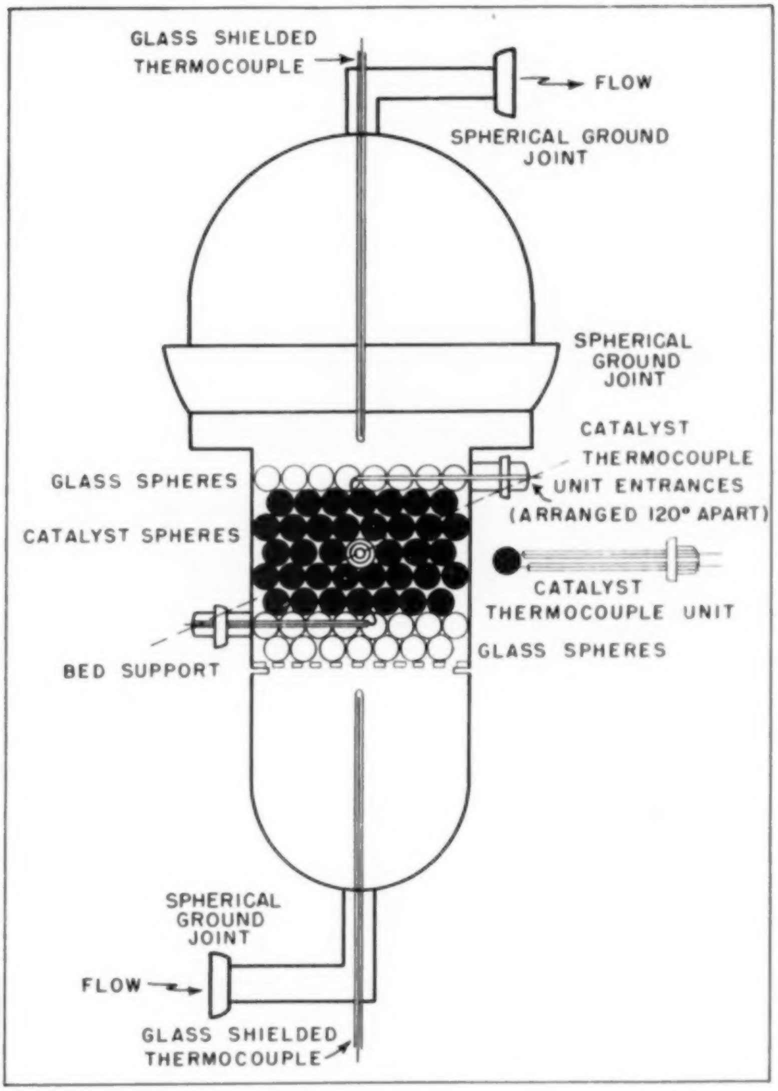

Fig. 1. Details of fixed bed reactor.

(*8, 10, 16, 18*); (2) sublimation of solids into gases (*11, 14*); (3) solution of liquids from porous particles into liquids (*9*); (4) solution of solids into liquids (*4, 5, 6, 12*).

The flow of fluids through packed beds of solids does not lend itself to mathematical analysis as readily as flow through conduits; therefore heat and mass transfer rates have frequently been expressed in terms of the heat and mass transfer factors, j_H and j_D, developed by Chilton and Colburn (*2, 3*).

As is to be expected in this type of work, values of j_D at a given Reynolds number, as determined by different investigators, differ from one another by as much as 100%, and significant differences are found between the results of the various workers as to the effect of the Schmidt number, the Reynolds number, particle diameter, and the transition from turbulent to laminar flow. On the whole, however, the agreement between the systems is relatively good, at least in the turbulent region, and has given rise to several generalized correlations. That of Gamson (*7*) plots $j_D/(1-\epsilon)^{0.2}$ against the Reynolds number $D_pG/\mu(1-\epsilon)$ and introduces a shape factor for packing other than spheres. A second generalized correlation, introduced by various authors to combine the data on single spheres with packed beds, employs for the velocity term the average interstitial condition within the bed, giving as the co-ordinates $j\epsilon$ and Re/ϵ. For a randomly packed bed of spheres, the system with which the present investigation is concerned, however, both general correlations and simple j_D vs. N_{Re} plots give approximately the same degree of agreement of the various data, since the void fractions of the systems employed by the various investigators are nearly identical. Therefore, the simpler plots were used to correlate the mass and heat transfer data obtained here and to compare them with previous work.

Experimental Procedure

CONSTRUCTION OF APPARATUS

The hydrogen peroxide vaporization unit, entrainment separator, and superheater used are described in Part I. The vapors leaving the superheater passed up through a packed bed and thence through a downstream sampling station, which, as in the catalyst tube studies, afforded a complete analysis of the gas stream leaving the bed.

Three different beds with inside diameters of 4.7, 4.8, and 7.5 cm. were used, a detailed diagram of the 4.7-cm. bed being shown in Figure 1. It consisted of a glass column with a total height of 2.35 cm. randomly packed with five layers of 0.200-in. diam. catalyst spheres. The

packed fraction was 0.604 for the 4.7 cm. bed, 0.573 for the 4.8 cm. bed, and 0.562 for the 7.5 cm. bed. The spheres, made of a polished catalytically active metal, retained a smooth surface throughout the runs. Two layers of inert Kimble Resistant Glass spheres below and one layer above the catalyst spheres helped to reduce entrance and exit effects. The ratio of bed diameter to particle diameter was large enough (approximately 10 to 1) to minimize wall effects. The bed was supported by a grid of glass rods fused together and resting on an indentation around the column. A 3-in. spherical ground joint at the top of the column provided access to the bed for construction and maintenance.

The temperature of the entrance and exit gas streams and the temperature of one catalyst sphere in each of the first, third, and fifth catalyst layers, proceeding from bottom to top, were measured. The thermocouples indicating gas temperatures were mounted in glass wells. The catalyst thermocouples were threaded through holes drilled in the catalyst spheres and were made of platinum-10 % rhodium, platinum couples in order to withstand the corrosive action of peroxide vapor. The decomposition occurring on the short lengths of exposed thermocouple wire surface could be neglected in comparison with the total decomposition in the bed. As indicated in the insert in Figure 1, the catalyst thermocouples were constructed by leading the

two wires into the reactor through two glass tubes blown onto a spherical ground joint. The wires were connected by a lap weld, which was then pulled into the catalyst sphere. The position of the sphere on insertion into the bed was dictated by the necessity for avoiding contact between the thermocouple wires and other spheres. Therefore the sphere containing the bottom-layer thermocouple was placed in the center of the layer with the wires being brought down through the glass packing; the middle-layer thermocouple, at the edge of the bed; and the top-layer thermocouple, in the center of the layer, its wires brought out through the layer of top glass spheres.

The 7.5-cm. bed was of the same general design but had only four layers of catalyst spheres. The catalyst spheres measuring bed temperature were placed in the first, third, and fourth layers, their positions in the layers being the same as described above. In operation the bed was insulated with several inches of glass wool and covered with aluminum foil. After steady state was reached, thermocouple voltages, condensate samples, and oxygen rates were obtained as described in Part I.

The range of inlet hydrogen peroxide concentrations investigated varied from 5 to 24 wt. %. In the 4.7- and 4.8-cm. beds the flow rates used resulted in Reynolds numbers, D_pG/μ, of from 22 to 161 and those with the 7.5-cm. bed ranged from 15 to 60. As was the case in the catalyst tube, the catalyst surface temperature in the system, determined principally by the other variables, was found to vary from 400° to 900° F.

CALCULATION OF DATA

The measured values of gas composition, flow rate, and temperature were used to obtain decomposition rates and concentration and temperature driving forces. These, in turn, gave heat and mass transfer coefficients which were correlated by means of j-factor expressions. The film properties necessary in calculating the factors were based on the logarithmic mean of the values at the entrance and exit film temperatures. An arithmetic mean of the gas and catalyst temperatures was employed for the film temperature. The mass transfer coefficients were based upon the logarithmic mean of the entrance and exit partial pressure differences from the catalyst surface to the fluid. Because of the heat flow characteristics in the bed, heat transfer coefficients determined on an over-all basis are in error; therefore point values of the heat transfer coefficients, which are more accurate, were determined at the center of the bottom catalyst layer of the bed.

Results

The results obtained from the studies on the packed bed are given in Tables 1 and 2* and Figures 2-4. Table 1 summarizes the experimental data and the results for mass and heat transfer calculated on an over-all basis. Table 2 contains the results recalculated for the temperatures and concentrations existing at the center sphere of the first layer of catalyst spheres. Except for two runs included in the tables but omitted from the figures, the possible error due to experimental measurements was about 2% in the value of j_D and approximately 15% for point values of j_H in runs with small temperature gradients. In most runs, however, the error in point values of j_H was probably less than 5%. Considerable hydrogen peroxide decomposition occurred on the glass surfaces in the two runs omitted.

* See footnote on page 504.

that the average deviation of the data is only 5.8% over the larger spread of Reynolds numbers makes the conclusion perhaps more convincing here than for the corresponding data obtained with the catalyst tube.

MASS TRANSFER CORRELATION

The mass transfer results are shown in Figure 2 with several other sets of data from the literature. The internal agreement of the present values is excel-

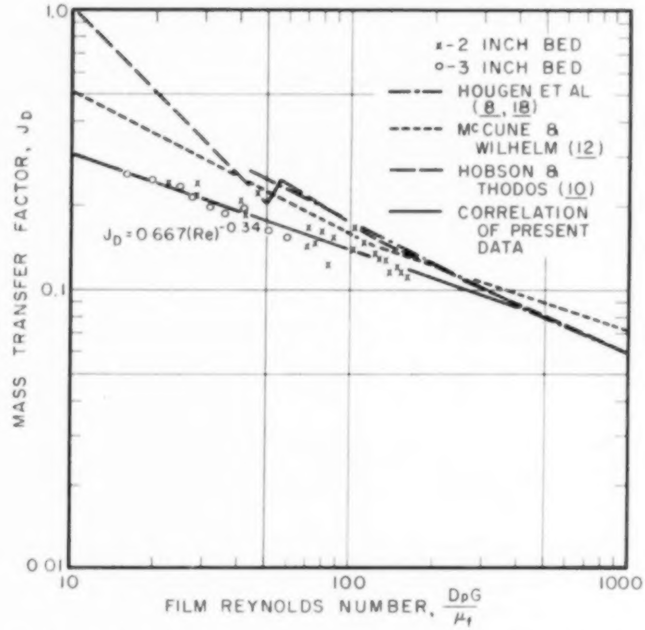

Fig. 2. Variation of mass transfer factor with Reynolds number in packed beds.

Discussion of Results

PROOF THAT THE REACTION IS DIFFUSION-CONTROLLED

The facts that lead to the conclusion that the reaction is diffusion-controlled under the experimental conditions were presented and discussed in Part I. This is further shown by the correlation of the packed-bed studies as given in Figure 2. If surface reaction completely controlled, the slope of the line should be −1.0. In studies where diffusion rate alone controlled, other workers have indicated slopes of −0.40 to −0.50. The slope for the data reported here is −0.34, which is slightly lower than even the lowest slope previously reported for a diffusion-controlled system. The fact

lent, giving an average deviation of 5.8% from the best line.

$$j_D = \frac{k_G p_{BM} M_M}{G} = 0.667(N_{Re,f})^{-0.34} \tag{61}$$

As shown by other investigators who have compared data obtained with different sphere diameters, the influence of particle diameter is accounted for by the use of a Reynolds number on a particle diameter basis; therefore this correlation should apply to similar systems with different particle sizes.

Temperature differences between bed and stream of up to 500° F. appear to play a negligible role in determining the values of j_D since no trend with temperature could be detected. The physical

properties of the stream were evaluated at the film temperature, although, as in the tube studies, the changes with temperature are such as to give almost as good a correlation on the basis of stream properties.

It is interesting to note that the data fall on a straight line and do not exhibit the break which other investigators have found in the range of Reynolds numbers examined. The straight line of the present work is lower in slope than the transitional and laminar region lines of earlier workers but represents a fairly good continuation of their turbulent region lines. This indicates that the flow pattern remains turbulent and does not transform into transitional or laminar patterns even at Reynolds numbers less than 20. Such behavior is in agreement with the findings of Bernard and Wilhelm (*1*), who demonstrated that the change from turbulent to laminar flow could occur at Reynolds numbers of from 10 to 1000 depending on the physical system involved. It seems entirely plausible that the system here would remain turbulent throughout the entire range investigated, especially considering the additional effect of heat transfer through the film.

Figure 2 also shows the results of this work to be somewhat lower than the majority of the data obtained by other investigators, although it is true that the wide spread of the earlier results covers the present work. This difference does not appear to be due to thermal diffusion, counterdiffusion, or temperature gradients. Rather, the most probable cause is the smooth surface of the spheres used. Other investigators employed either modified spheres made by pelletizing solid powders or porous spheres, both having rough surfaces. Such rough surfaces could give a higher value of j_D by the actual surface area being greater than that calculated from the sphere diameter or, more probably, by the increased turbulence and, therefore, increased mass transfer resulting from the roughness.

The experimental values give excellent internal agreement when plotted by use of the generalized Gamson functions, although they average 14% below the values recommended by an extension of the turbulent line of Gamson. In this respect, they agree with the fixed-bed data of McCune and Wilhelm (*12*), which follow the extension of the turbulent line on a Gamson plot to a Reynolds number of 23. Extreme precaution in the use of the generalized correlation is called for in the region of Reynolds numbers below 100 since large variations may occur depending on the characteristics of the system being employed.

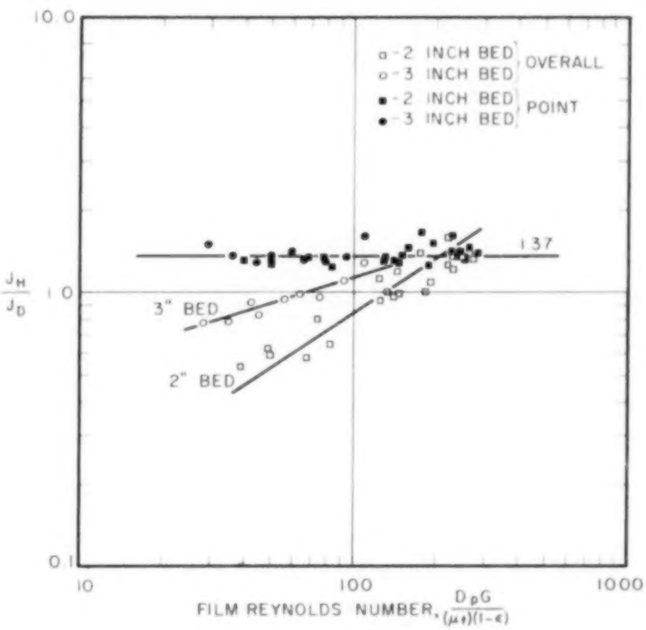

Fig. 3. Ratio of transfer factors, J_H/J_D, for over-all and point conditions.

HEAT TRANSFER CORRELATIONS

The complex shape of the reactor prohibited any attempts to wind it with electrical resistances and thereby establish adiabatic flow conditions. Consequently substantial heat losses occurred through the insulation. Over-all heat transfer coefficients from catalyst spheres to gas stream were calculated by multiplying the measured rate of decomposition by the heat of reaction to obtain the total heat release rate on the catalyst surfaces. The logarithmic mean temperature difference was calculated from the measured catalyst sphere temperatures at the top and bottom of the bed and the inlet and exit gas temperatures.

The heat transfer coefficients thus calculated, converted to j_H factors, are plotted in Figure 3 (two lower lines) as the ratio of j_H/j_D vs. Reynolds number. Heat losses have a negligible effect on the value of j_D but give an erroneously low value of the exit gas

temperature, with resulting high value of the temperature difference and low value of j_H. As would be expected j_H, or the ratio of j_H/j_D as calculated on an over-all basis, increases with Reynolds number, since heat losses are proportionately less at higher flow rates. Likewise at a given Reynolds number, the ratio is lower for the 2-in. bed than the 3-in. bed, which is consistent with that expected with the surface-volume ratios of the two systems. The considerable scatter of these data is caused by the relatively low temperature difference which existed at the top of the bed; consequently a small error in temperature measurement would appear as a large error in j_H. Because of the errors caused by heat losses, these over-all coefficients are of interest largely in comparison with the point values determined separately. Such point values could be obtained accurately by choosing for this purpose the center catalyst sphere in the first catalyst layer, where the temperature difference between catalyst and gas stream is the highest.

The calculation proceeds from the fact that all the heat is generated on the surface of the catalyst sphere and this must all be transferred back to the gas

stream by conduction and convection. The catalyst spheres throughout the bed have very nearly the same temperature and are in point contact only with one another. For these reasons heat transfer between the chosen sphere and the rest of the catalyst bed by solid-to-solid conduction and by radiation may be neglected. Heat transfer by radiation from the chosen sphere to the surroundings of the packing is negligible because of the relatively low emissivity of the metal catalyst surface and the relatively small solid angle through which this catalyst sphere is exposed to the noncatalytic surroundings. Calculations indicate that heat transfer by this mechanism accounted for but a fraction of 1% of the total in the various runs made.

To obtain these point values, average gas temperatures and concentrations over the first layer of spheres were calculated by means of the relationship:

$$\log F = KH \qquad (62)$$

where F is the fraction of hydrogen peroxide *not* decomposed, H is bed depth, and K is a constant. This expression was developed from the detailed analysis of the catalyst tube and can also be obtained approximately from the relationship

$$dp/dH = K'p, \qquad (63)$$

which expresses the fact that in a diffusion-controlled system the change in partial pressure with height is almost directly proportional to the partial pressure. Integration of Equation (63) shows that the logarithm of the partial pressure, very nearly proportional to the fraction *not* decomposed, is linear in bed depth. Since F is known for inlet and exit conditions, a semi-logarithmic plot of F vs. height in the bed allows the calculation of the partial pressure and gas temperature at the center of the first layer of spheres, that is, for the bed five sphere layers deep, the average value of F for the first layer is taken at one-tenth of the distance through the bed.

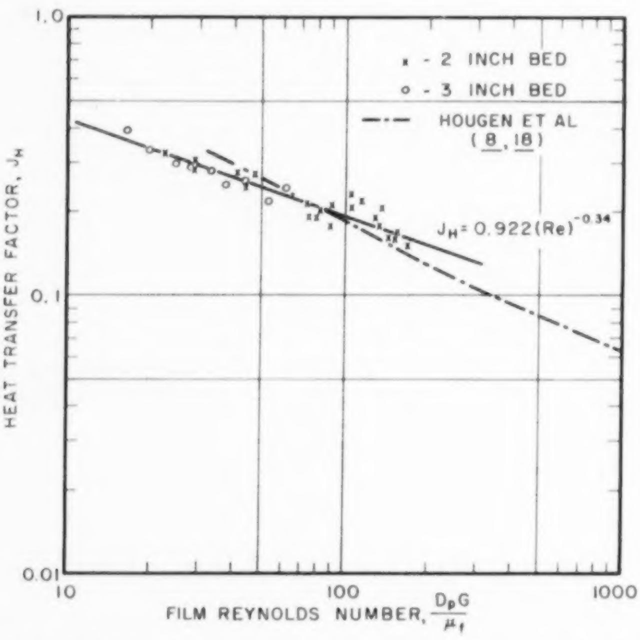

Fig. 4. Variation of heat transfer factor (on a point basis) with Reynolds number in packed beds.

Figure 4 depicts the correlation which was obtained between the point value of j_H and the Reynolds number. The data have an average deviation of 6.4% from the best line:

$$j_H = 0.992(N_{Re,f})^{-0.34} \qquad (64)$$

The values are also seen to compare very well with the heat transfer data of Hougen et al. (*9, 18*) although, as in the case of mass transfer, the present data exhibit a smaller slope than the earlier correlations. However, it would seem that either Equation (64) or the earlier correlation can be employed to predict the heat transfer characteristics of a packed bed.

The heat transfer data agree closely with the generalized Gamson correlation; the values average 10% above the continuation of the turbulent line of his correlation.

RATIO OF j_H/j_D

Values of this ratio were obtained by considering the point conditions at the center sphere of the first catalyst layer. The technique used for obtaining j_H is described above. Each point value of j_D was obtained from the same value of k_G as that used in calculating the over-all value of j_D, but k_G is multiplied by slightly different values of the other variables. The point values of j_D are practically the same as the over-all values shown in Figure 2, all the points being slightly displaced downward and to the right, parallel to the correlation. However, as shown on Figure 3, the point values of the j_H/j_D ratio now give an average deviation of 5.5% from the value 1.37. The fact that this ratio does not vary with Reynolds number or hydrogen peroxide concentration (which in turn largely determines catalyst surface temperature) is strong support of the argument that heat transfer by radiation from the catalyst sphere studied was negligible.

Two observations support the belief that the j_H/j_D ratio throughout the bed is also greater than one and equal to about 1.37.

1. The fact that the catalyst surface temperatures usually increased with bed height supports this conclusion.

2. Values of the over-all ratio are shown in Figure 3 to agree with 1.37 at high Reynolds numbers where the effect of heat losses and regenerative heat flow are minimized.

The only other data on simultaneous heat and mass transfer in a packed bed are those of Gamson, Thodos, and Hougen (*8*), who related heat and mass transfer factors from the evaporation of water into air by the expression $j_H/j_D = 1.076$. However, it can be shown (*15*) that this value results from the assumption of wet-bulb temperature at the surface of the porous spheres and that the value 1.076 can be obtained independently of the rate data from the slope of the adiabatic saturation line and the physical characteristics of air. The assumption may not be entirely correct (*10*), and any error would lead to too low a value for the ratio. However, any error introduced by assuming the surface to be at the wet-bulb temperature can be shown to affect j_D much more than j_H, and so it may be assumed that the values of Gamson,

Thodos, and Hougen for j_H are more reliable than those for j_D.

The value found here for the ratio differs somewhat from unity but is within the range of 0.8-1.5 reported in the literature for evaporation of liquids in various systems. This range is not surprising in view of the fact that simple heat transfer in carefully controlled tube systems gives data points varying by 20 to 30%. No reason can be advanced for the difference of the present value from unity.

TEMPERATURE DISTRIBUTION

The catalyst temperature throughout the bed tended to be uniform both laterally and transversely and exhibited a slight rise in catalyst temperature in the direction of flow, Table 2. Since the j_H/j_D ratio in the bed was found to be 1.37, it would be expected that the surface temperature at any point should be less than the adiabatic reaction temperature (Equation 59, Part 1), the difference between the two temperatures being larger at high reactant concentrations and therefore, at higher temperature differences between surface and stream. This occurs at the entrance to the bed. Correspondingly, the bed temperature should increase with length, as was found experimentally.

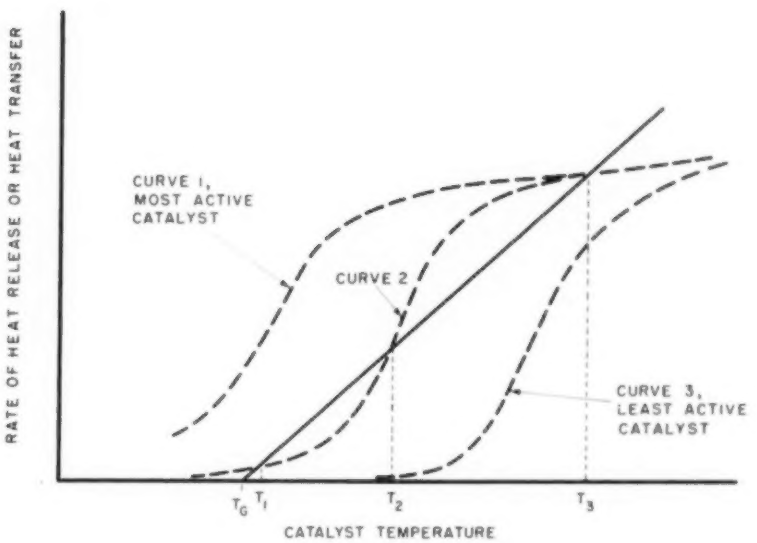

Fig. 5. Inferred rate of heat release (dashed curves) and heat transfer (solid line) as a function of catalyst temperature and activity, after Wagner (17).

HOT SPOTS

When a relatively rapid exothermic reaction occurs in a packed bed, it has been observed that individual pieces of the packing, more or less randomly distributed, may glow red hot while neighboring pieces are much cooler, even when in direct contact with the red hot pieces. This has occurred on passing hydrogen peroxide vapor through various packed beds and also in other relatively rapidly reacting chemical systems. In many systems it is desirable to use a highly-active catalyst yet to avoid the occurrence of such hot spots which might lead to rapid loss of catalyst activity caused by the high local surface temperatures. This phenomenon can be understood by considering how the rates of heat transfer and of chemical reaction vary with temperature and how this affects the catalyst surface temperature. A theoretical analysis of this problem has been made by Wagner (*17*). It will be discussed here in a qualitative fashion, followed by a quantitative consideration of the surface temperatures which may be reached.

When a gas passes through a differential packed bed and reacts exclusively on the surface of the solid, all the heat released by reaction is transmitted back to the gas stream, and if this occurs by conduction and convection only, the temperature difference between catalyst and gas will be directly proportional to the rate of heat transfer, as represented by the solid straight line on Figure 5, where T_G represents a fixed gas temperature. If the bed consists of solid particles of moderately high and equal activity, the rate of heat release on the solid surface is represented by dashed curve number 2 on the Figure. The chemical reaction rate is relatively low at low temperatures but usually increases exponentially with surface temperature until the rate of diffusion becomes important, when the curve is inflected to a further slow rise with temperature characteristic of molecular diffusion, and eventually crosses the heat transfer curve. Since the rate of heat release on the surface must equal the rate of heat transmission to the gas under steady state conditions, it is evident that the only stable surface temperatures are T_1, a reaction-rate controlled condition, or T_3, a diffusion-controlled condition. The metastable point T_2 is in effect a kindling temperature. If the catalyst surface were brought by some means momentarily to a temperature between T_1 and T_2, it would cool down to T_1 under steady state conditions. Correspondingly, if it were brought momentarily to a temperature between T_2 and T_3, its steady state temperature would be T_3. Curve 1 represents a more active differential

packed bed in which the rate is completely diffusion-controlled. Curve 3 represents a relatively inactive solid on which the reaction will be reaction rate-controlled with consequent surface temperature very close to that of the gas. An increase in the gas temperature shifts the diagonal heat release line to the right without appreciably affecting its slope or the position of the heat release curve, and consequently increases the probability of the reaction becoming diffusion-controlled. An increase in the concentration of the reacting species stretches the heat release curve upwards and also increases the probability of the reaction becoming diffusion-controlled. As the reacting gas passes through an integral adiabatic packed bed, these two effects act in opposite directions, and under the simplifying circumstances discussed below the temperature reached by the catalyst surfaces in a diffusion-controlled adiabatic reaction is constant throughout the bed and equal to the adiabatic reaction temperature of the gas entering the bed. An increase in gas velocity increases the heat transfer coefficient and thereby the slope of the heat transfer curve. However it also increases the mass transport coefficient which displaces upwards the right-hand side of the heat release curve, which

represents the diffusion-controlled portion, while causing no change in the left-hand portion of the curve, where chemical reaction controls.

The analysis below shows that if mass and heat transport vary in the same manner with velocity, as usually assumed, then the temperature reached in the diffusion-controlled case is independent of gas velocity. It is seen that the hydrogen peroxide system as studied here follows the behavior epitomized by curve 1 at all points in the bed.

Since different pieces of catalyst may vary somewhat in activity, it is apparent that the hot spot phenomenon occurs in beds containing packing of various intermediate activities. The hot pieces of catalyst possess at that time relatively high activities and are diffusion-rate controlled, whereas the other pieces of catalyst are reaction-rate controlled.

It was shown in Part I that the temperature reached by a solid surface which is diffusion-controlled may be estimated from Equation (59).

$$\Delta T = (j_D/j_H)(P/P_{BM})(N_{Pr}/N_{Sc})^{2/3} (C \cdot \Delta H/C_p \cdot \rho) \qquad (59)$$

Under the relatively common conditions where N_{Pr} approximately equals N_{Sc}, and the reacting component is relatively dilute, this relationship states that the catalyst surface temperature equals the adiabatic reaction temperature of the system. In any particular case, however, it is possible for the surface temperature to be either above or below this value, depending upon the values of the various variables. Equation (59) and its derivation suggest several ways in which hot spots can be avoided. Lowering the gas temperature is, of course, a possibility, either by decreasing inlet gas temperature or by abstracting heat from the reactor. It may be possible to lower the concentration of the reacting species. For a given inlet temperature this will, of course, reduce the temperature of the exit gases as well as reduce the possibility of hot spot formation. For example, catalyst packed beds on which carbon has been deposited are commonly regenerated by burning off the carbon, but excessive surface temperatures leading to catalyst deactivation may be prevented by holding the oxygen concentration down to a low level by recycling combustion gases. In some cases it might be effective to mix in with the catalyst a substantial amount of inert solid material having as high a radiation absorptivity coefficient as possible to act as a heat sink for heat transfer by radiation from potential hot spots.

The situation becomes more complicated when the procedure involves entrance of reactants as liquid and conversion to a hot product gas before exit. In such a case it is possible for the flow and heat transfer pattern to be such as to permit liquid to become vaporized and heated while retaining essentially its initial composition. This may occur more or less uniformly throughout the upstream inlet zone by regenerative heating from the hotter downstream reaction zone. Alternately at a given distance downstream there may be considerable variation in composition and temperature in the radial direction. Either possibility can cause individual portions of the catalyst to reach surface temperatures substantially above the adiabatic reaction temperature as calculated for reaction starting with the liquid phase.

Acknowledgment

The material presented is based on the Sc.D. thesis of Hyman Resnick, and the S.M. theses of Ralph L. Wentworth, Stanley R. Meeken, and Arthur R. Winters, all of which are based on work done in the Department of Chemical Engineering at Massachusetts Institute of Technology. The authors also wish to acknowledge the assistance of Peter J. Ceccotti and Richard M. Rome in the program of study. Financial support was received from the Office of Naval Research under Contract N5ori-07819, NR-092-008.

Notation

a = catalyst surface area per unit volume in bed, sq.ft./cu.ft.
A = area, sq.ft.
C_p = specific heat at constant pressure, B.t.u./(lb.)(° F.)
D = diffusion coefficient, sq.ft./hr.; D_{AB}, diffusion coefficient of component A through component B
D_p = particle (sphere) diameter, ft.
f = fraction hydrogen peroxide in feed decomposed
F = fraction hydrogen peroxide in feed not decomposed, $f + F = 1$
G = mass flow rate, lb./(sq.ft.)(sec.)
h = heat transfer coefficient, B.t.u./(hr.)(° F.)(sq.ft.)
H = height of packed bed, ft.
j_D = mass transfer factor, $(k_G p_{BM} M_M/G)(N_{Sc,f})^{2/3}$, dimensionless
j_H = heat transfer factor, $(h/C_p G)(N_{Pr,f})^{2/3}$, dimensionless
k_G = coefficient of mass transfer, lb. moles/(hr.)(sq.ft.)(atm.)
M = mlecular weight, lb./lb. mole
N_{Pr} = Prandtl number, $(C_p\mu/k)$, dimensionless
N_{Re} = Reynolds number, (D_pG/μ) in bed, dimensionless
$N_{Re,M}$ = Reynolds number, $D_pG/\mu(1-\epsilon)$
N_{Sc} = Schmidt number, $(\mu/\rho D)$, dimensionless
p = partial pressure, atm.; p_{BM}, mean partial pressure of inerts
Q = rate of heat transfer, B.t.u./hr.
T = temperature, ° F.; T_w, wall temperature; T_a, average film temperature; T_f, film temperature; T_s, stream temperature
w = rate of decomposition, lb. moles/hr.
W = total rate of flow, lb./hr.
y = mole fraction hydrogen peroxide in vapor
Δ = finite difference
ϵ = void fraction in packed bed
μ = viscosity, lb./(sec.)(ft.)
π = 3.1416
ρ = density, lb./cu.ft.

SUBSCRIPTS:

A = component A, referring usually to hydrogen peroxide
B = component B, referring usually to mixture of steam and oxygen
f = film conditions
$l.m.$ = log mean value
M = mean value
p = point value; in bed referring to conditions at center sphere of bottom layer
1 = entrance of bed
2 = exit of bed

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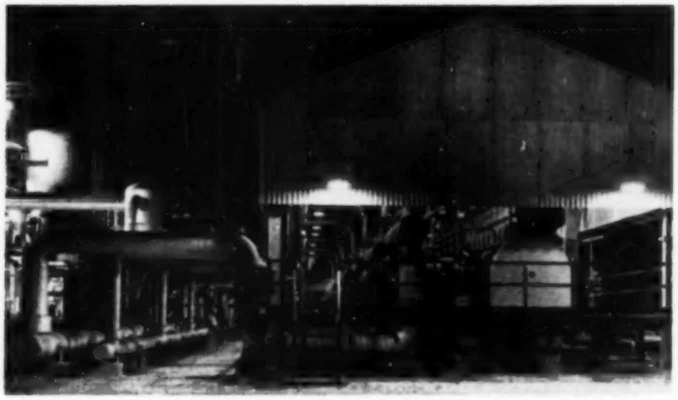
ethylene compressibility factors



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Commercial operations involving orifice meter measurements of the flow of ethylene through pipe lines required accurate compressibility factors in the low- and medium-pressure ranges. This paper presents experimental data in the pressure range 50 to 600 lb./sq.in.abs., at temperatures of 20 to 100° F. A mathematical extrapolation with the use of an equation of state fitting the experimental results is employed to extend the data to −20° F.

The large-scale manufacture of ethylene by the oil industry has prompted pipe-line distribution of this important petrochemical in order to effect economies in transportation costs. Accurate measurements of gas flow with standard orifice meter equipment necessitated an investigation of all phases of current metering practice. One of the basic orifice coefficient correction factors is the supercompressibility factor. This multiplier is the square root of the reciprocal of the compressibility factor Z. The objective of the work described in this paper was to establish the accuracy of the available volumetric data and to

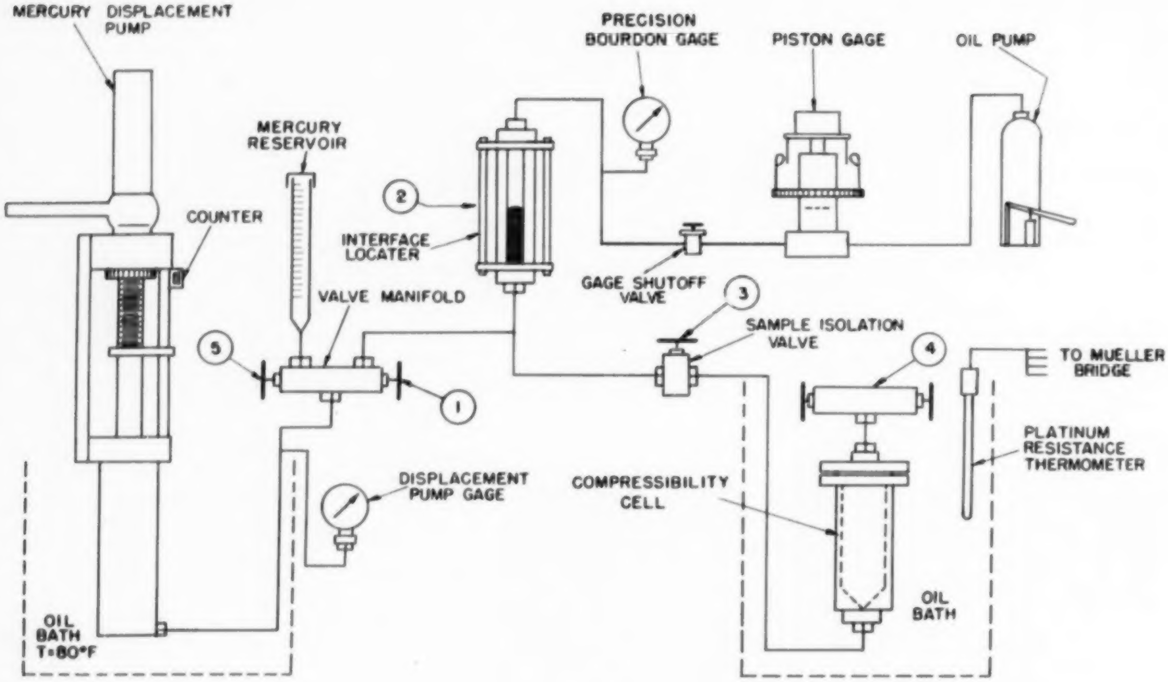

Fig. 1. Gas compressibility equipment.

make experimental measurements where necessary.

A review of the literature revealed little adequate experimental information in the temperature and pressure ranges originally desired, i.e., 40 to 100° F., and 50 to 600 lb./sq.in.abs. respectively.

Amagat's (*1, 2*) *P-V-T* measurements on ethylene terminate at 36 atm. Data of Michels, de Gruyter and Niesen (*12*), and Michels and Geldermans (*13*) cover a wide range with some data reported in the region of interest. Density information used by York and White (*14*) were obtained by extension of the Michels, *et al.* data with the Benedict (*4*) equation of state. The 24.95° C. isotherm was investigated by Masson and Dolley (*10*) from 5 to 125 atm., but the accuracy of the results has been questioned (*7, 8*). Other data found in the survey were, in general, fragmentary or outside the desired region.

In view of the limited data available and because of some disagreement between the various sources, an investigation of the *P-V-T* properties of ethylene in the initially specified operating range was undertaken. As the work was nearing completion, a further analysis of the pipe-line problem indicated the possibility of encountering temperatures as low as −20° F. due to Joule-Thomson expansion effects. The temperature range was therefore extended to 20° F. since this was the lowest temperature that could be achieved without extensive modification of the experimental equipment. Compressibility factors to −20° F. were obtained by a limited mathematical extrapolation of the experimental values.

Equipment and Method

The experimental method used in these determinations involved the measurement of the pressure and volume of a fixed mass of ethylene gas at various temperatures. The apparatus assembled was quite similar to that employed by other investigators, who used variable volume cells, and is shown schematically in Figure 1.

Essentially the apparatus was comprised of five components: a high pressure compressibility bomb, a calibrated mercury displacement pump, an accurate free piston pressure gauge, a temperature-measuring and -controlling system, and sample charging equipment. The compressibility cell consisted of a heavy-walled steel vessel with a nominal capacity of 435 cc. and was completely immersed in a well-agitated oil bath. The volume of the cell assembly was obtained by filling the system between points (3) and (4) with mercury and weighing the contents. Several trials indicated that the volume of the system was known to ±0.05 cc. at calibration conditions. Changes in cell volume with pressure were experimentally determined with a large dilatometer, and volume changes due to temperature were calculated.

A 200-cc. capacity mercury displacement pump was used to vary the volume of the gas. The pump was isolated from the remainder of the system and adjusted to the calibration conditions of 650 lb./sq.in. gauge and 80° F. at the time of each *P-V-T* measurement.

Bath temperatures were measured with a 25-ohm platinum resistance thermometer and a Mueller-type bridge. Thermometer constants were checked by comparison with a resistance thermometer certified by the Bureau of Standards. Temperature was controlled to ±.02° F. by means of equipment similar to that described in the literature (*3, 6, 9*).

The effective area of the piston gauge was obtained by the methods of Meyers and Jessup (*11*) and verified by measuring the vapor pressure of CO_2 at the ice point, as suggested by Bridgeman (*5*).

The interface locater, made from a small bore glass tube, provided a reference mark (2) from which the mercury head was determined. Positioning of the mercury-oil interface in the tube was accomplished by adjusting the weights on the piston gauge. The difference in mercury levels was then obtained by an accounting of the mercury injected. Necessary corrections for variation of mercury density due to pressure and temperature were made. An oil head correction was eliminated by placing the reference mark

at the same level as the base of the piston gauge. The effect of capillary depression at the mercury-oil interface was experimentally determined.

Samples were transferred from a small charging bomb to the compressibility cell by condensation at liquid nitrogen temperature. Gas loss in the small bore connecting tubing was found to be negligible. The mass of ethylene charged was obtained by weight difference to within ± 0.0005 g.

After the transfer was completed, the compressibility bomb was connected to the rest of the measuring system (Figure 1). The lines were filled with mercury between (1), (2), and (3), and with oil between (2) and the gauge shut-off valve. Trapping of air was prevented by previously evacuating these lines.

Volume changes of the line system due to compression of valve stem and gasket packing were evaluated before the injection of mercury to the cell was started. Precautions were taken also when injecting the initial volume of mercury to prevent trapping of gas in the sample isolation valve or in the line connecting it with the cell.

Volume and pressure measurements were made both on injecting and withdrawing mercury. It was thought inadvisable to compress the gas to a volume smaller than 100 cc. since the percentage error in the volume measurements, obtained by difference between known-bomb volume and injected-mercury volume, would begin to exceed imposed limits. Because of this limitation three separate charges of ethylene to the compressibility cell were necessary in order to cover completely the desired range of temperature and pressure.

Gas Purity

The ethylene gas used in this work was purchased from the Ohio Chemical Company. The purity of the gas was thoroughly investigated with a mass spectrometer, combination mass spectrobeter-low temperature distillation, and olefin absorption techniques. The major impurity found was nitrogen (0.12%). Trace quantities of hydrogen, oxygen, propylene, and butylene were found, but the sum of these impurities, according to mass spectrographic analysis, was less than 0.20%. It was estimated that the presence of these small amounts of impurities would not appreciably affect the absolute accuracy of the data and therefore further purification of the gas was not considered essential.

Discussion of Results

A summation of the probable accuracy of the measurements indicates that the uncertainty of the data is $\pm 0.25\%$ when based on the compressibility factor $Z = PV/nRT$. The value of 10.731 (cu.ft.) (lb. sq.in.abs.)/(lb. mole)(° R.) was used for R, and 28.052 was used for the m.w. of the gas.

The experimental data obtained are shown graphically in Figure 2 as Z vs. P at constant temperature. Different symbols are used for each charge in plotting the curves, and good precision is indicated by the close agreement at overlapping regions. Because of an overlooked conversion from international to absolute ohms, when adjusting the Mueller bridge and thermo-regulator for what was to have been the initial 80° F. isotherm, the temperature was actually 79.74° F. The same temperature was used on subsequent charges at this temperature level in order to secure consistent data.

A tabulation of Z vs. P in 25 lb./sq.in. increments is given in Table 1. Data were read from a large plot of Figure 2, and an appropriate interpolation made to obtain values at 80° F.

The mathematical procedure used in extending the data to −20° F. involved fitting an equation to the experimental points with sufficient precision that the

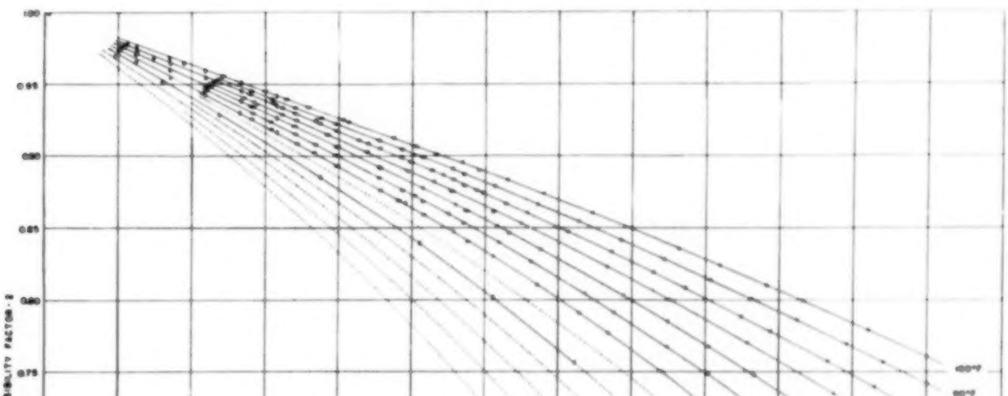

Fig. 2. Compressibility factors for ethylene.

Table 1.—Compressibility Factors for Ethylene

Pressure lb./sq.in.abs.	Temperature ° F. 20	40	50	60	70	80	90	100
50	.9712	.9743	.....	.9772	.....	.9798	.....	.9822
75	.9560	.9612	.....	.9657	.....	.9695	.....	.9730
100	.9406	.9478	.....	.9539	.....	.9593	.....	.9637
125	.9251	.9337	.9381	.9419	.9451	.9489	.9513	.9542
150	.9093	.9202	.9254	.9301	.9339	.9384	.9416	.9451
175	.8932	.9063	.9126	.9181	.9229	.9278	.9317	.9357
200	.8770	.8925	.8996	.9061	.9114	.9172	.9218	.9262
225	.8601	.8782	.8863	.8933	.8998	.9065	.9118	.9167
250	.8428	.8638	.8732	.8812	.8884	.8956	.9019	.9075
275	.8243	.8490	.8595	.8686	.8770	.8850	.8919	.8981
300	.8054	.8336	.8452	.8558	.8652	.8738	.8814	.8889
325	.7856	.8173	.8303	.8420	.8528	.8620	.8710	.8792
350	.7653	.8007	.8152	.8281	.8403	.8504	.8603	.8694
375	.....	.7833	.7994	.8138	.8272	.8387	.8493	.8595
400	.....	.7654	.7832	.7995	.8141	.8267	.8382	.8494
425	.....	.7465	.7666	.7845	.8006	.8142	.8270	.8389
450	.....	.7265	.7495	.7689	.7865	.8013	.8154	.8282
475	.....	.7055	.7316	.7530	.7721	.7888	.8035	.8175
500	.....	.6835	.7127	.7365	.7576	.7755	.7918	.8065
525	.....	.6599	.6925	.7193	.7422	.7621	.7796	.7952
550	.....	.6336	.6715	.7016	.7267	.7482	.7673	.7839
575	.....	.6043	.6488	.6831	.7106	.7340	.7545	.7722
600	.....	.....	.6251	.6631	.6940	.7191	.7417	.7605

Table 2.—General Constant for Equation of State

Units V — cu.ft./lb., T — ° R.

A_1	-3.47584×10^{-2}
A_2	48.3458
A_3	$42.8199 \times 10^{+5}$
A_4	-1.52043×10^{-3}
A_5	10.8041
A_6	$-13.5378 \times 10^{+6}$
A_7	$25.6697 \times 10^{+8}$

data could be safely extrapolated over the limited temperature range desired. The procedure used was the common least squares method. The equation employed seven parameters, instead of the usual five of the Beattie-Bridgeman equation, and was considered sufficiently accurate for the small pressure range involved:

$$1 - Z = \left(A_1 + \frac{A_2}{T} + \frac{A_3}{T^3}\right)\frac{1}{V} + \left(A_4 + \frac{A_5}{T} + \frac{A_6}{T^3}\right)\frac{1}{V^2} + \frac{A_7}{T^3V^3}$$

The values of the constants obtained are listed in Table 2. These are based on the following system of units; V — cu.ft./lb., T — ° R.

The equation was used to calculate compressibility values for the temperature range 30 to $-20°$ F. Results are plotted on Figure 2 as dotted lines, and a tabulation at 50 lb./sq.in. intervals, read from an enlarged chart, is given in Table 3.

In order to facilitate the calculation of other desired points at a given temperature, the equation can be rewritten in the form

$$1 - Z = \frac{B_1}{V} + \frac{B_2}{V^2} + \frac{B_3}{V^3}$$

The values of B_1, B_2, and B_3 are tabulated in Table 4 for the several temperatures.

The least-squares solution fits the data extremely well, the root-mean-square deviation being 0.06% with a maximum deviation of 0.24%. However, because of the small pressure range covered, the following limitations should be observed. The equation should not be extrapolated to higher pressures. It does not, in fact, produce the typical minima observed at higher pressures and temperatures (at or above the critical temperature). The constants of the equation should not be interpreted in terms of any physical quantities such as molecular volume, van der Waals' attraction, etc.

Table 3.—Compressibility Factors from Equation of State

Pressure lb./sq.in.abs.	Temperature ° F. −20	−10	0	10	30
50	.9613	.9638	.9669	.9689	.9727
100	.9214	.9270	.9323	.9369	.9444
150	.8789	.8875	.8960	.9030	.9154
200	.8332	.8459	.8572	.8676	.8855
250		.8005	.8161	.8300	.8537
300			.7716	.7898	.8199
350				.7451	.7840
400					.7457
450					.7021
500					.6498

Table 4.—Isotherm Constants for Equation of State

T ° F.	$B_1 \times 10^2$	$B_2 \times 10^3$	$B_3 \times 10^4$
100	7.6044	−3.622	1.46
90	7.8975	−3.700	1.55
79.74	8.2147	−3.800	1.64
70	8.5327	−3.917	1.73
60	8.8776	−4.060	1.83
50	9.2435	−4.231	1.94
40	9.6317	−4.433	2.06
30	10.0434	−4.670	2.19
20	10.4825	−4.946	2.33
10	10.9497	−5.267	2.48
0	11.4496	−5.638	2.64
−10	11.9836	−6.065	2.82
−20	12.5572	−6.558	3.02

The equation is considered quite good for temperature extrapolation, however. As a matter of fact, the physical data were obtained for 20° F. while these calculations were in progress and the calculated points were found to agree within the experimental accuracy.

Comparison of the experimental results with the limited data from the literature shows good agreement with those of Michels and Geldermans (*13*) whose measurements terminate at 16 atm.

Data of York and White (*14*) reveal a greater rate of change of Z with temperature at low pressures than the data presented here. However, the agreement is close at the higher pressures where the equation used by York and White can be better expected to fit the results of Michels and co-workers.

Values calculated with the Beattie-Bridgeman equation by the use of constants determined by Gillespie (*8*) from the data of Amagat were also compared. Except for the 100° F. isotherm, considerable disagreement exists.

Summary

Compressibility data reported here extend the available experimental information to low and medium pressure and temperature ranges not fully investigated previously. Although primarily intended for use in orifice meter measurements, the data should find other obvious uses.

Acknowledgment

The assistance of J. Darin in the calculation of the data and the help given by Messrs. M. C. Karpaw and N. H. Harrison in the experimental work and in processing the data are gratefully acknowledged.

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The photograph of ethylene compressor appearing on page 511 of this article—courtesy Jefferson Chemical Company.

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sulfur from hydrogen sulfide

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"Sulfur from Hydrogen Sulfide," a paper by Gamson and Elkins, was published in *Chemical Engineering Progress* (April, 1953, page 203), following its presentation at an A.I.Ch.E. Kansas City, Mo., meeting in 1951. At a subsequent A.I.Ch.E. meeting in Atlanta, Ga., in March, 1952, E. R. McCartney and A. L. Kohl presented a related paper in an oral discussion in which the writer participated. Unfortunately, McCartney, in the September, 1953, C.E.P., misstated this author's oral remarks and misinterpreted the published article. Accordingly, the following discussion is presented to clarify the position taken by the writer.

It is worth while to review first the existing P.V.T. data on sulfur gas. These are available in three publications (*1, 2, 3*). Both Preuner and Schupp (*3*), and Braune, et al. (*1*) have analyzed their data to show conclusively that the unusual compressibility of sulfur gas at total pressures as low as less than .01 atm. can be ascribed to an equilibrium existing between several molecular species of sulfur. Preuner and Schupp's analysis showed S_8, S_6, and S_2 to be present. The more accurate data of Braune, et al. published in 1951 gave S_8, S_6, S_4, and S_2 to coexist at temperatures below about 900° C. and 1 atm. pressure. It is important to emphasize that under these conditions the compressibility behavior of sulfur gas follows the ideal gas laws when consideration is given to the individual species present. In fact, the Braune studies are of an unusual degree of accuracy for such a difficult experimental system. Unique reconstruction of their data occurs when the free-energy equations derived for the equilibrium existing between the four species are used. Accordingly, it seems conclusively demonstrated that for pressures below about 2 atm. the compressibility of sulfur gas may be treated as the result of the ideal behavior of the species in equilibrium at a given temperature and pressure. Thus, this may be used as a basis for all thermodynamic equilibrium calculations.

With all this established, one can now proceed to the crux of the discussion. McCartney is in error when in his paragraph 2, second column, page 509, he implies that Gamson and Elkins did not appreciate that the equilibrium constants based upon pressure and fugacity could not have the same numerical value. Neither in our paper nor orally was there any statement that two or more values of K_p corresponded to the same value of K_f. Thus, McCartney's mathematical derivation has no bearing on the subject in question. The crux of my position, based upon McCartney's presentation and written matter, is that it is incorrect to calculate an equilibrium constant based upon the thermodynamic equilibrium between the species as covered by Equation (*24*) in the Gamson and Elkins' article and reproduced as

$$K_{17} = A(S_2)^a(S_6)^b(S_8)^c$$

and then to equate this equilibrium constant to the expression in our Equation (*22*)

$$K_{17} = \frac{(S_e)^x(H_2O)^2}{(H_2S)^2(SO_2)}$$

The discussion in the last column of Gamson and Elkins' paper on pages 207 and 208 conclusively demonstrates the thermodynamic inconsistency and inaccuracy resulting when such a calculation procedure is employed. Although McCartney agrees with Gamson and Elkins that this procedure is invalid, yet this is precisely the method employed by him in his written and orally presented paper at Atlanta, Ga. This is the procedure which was criticized and explained. It is gratifying to note that McCartney has recognized his error.

It should be emphasized further that, although McCartney criticizes the use of the derived functions from the gross P.V.T. data, he, in turn, has used the free-energy expressions obtained from the Preuner and Schupp experiments as developed by K. K. Kelly for the calculation of the equilibrium constant in accordance with Equation (24). The fact that McCartney has followed this method of calculation is well evident in the figures which accompany his own presentation. The errors obtained in the per cent conversion are well illustrated also when one considers the curve presented by McCartney as a function of temperature and that in Figure 5 of the Gamson and Elkins' article. The minimum yield given by McCartney in his figure occurs at a temperature of approximately 1,025° F., corresponding to about 62%. At one atmosphere the true rigorous minimum yield occurs at a temperature of approximately 1,060° F. and a yield of 53%. Other portions of the McCartney curve are similarly in error.

Typical errors encountered for the total sulfur pressure evaluated by Equations (26) and (27) in our article are given in Table 1. The true sulfur pressure is expresed by Equation (27). The value from Equation (26) is a concomitant of the use of K_{17} as indicated to both Equation (22) and (24).

It is worth while to consider McCartney's proposal to employ fugacities for future calculations in equilibrium systems involving sulfur. There is nothing wrong with utilizing fugacities for the calculation of equilibrium states. But this proposition with respect to sulfur gas must be looked into very closely. He has stated that the P.V.T. behavior of sulfur gas has been placed on a secure footing by the more recent data in (*1*) and (*2*). To the extent that these data corroborate, from a general standpoint, the earlier data of Preuner and Schupp, this is correct. Incidentally, in a paper on this same subject by Rush and Gamson to be run in C.E.P., revised calculations have been made by use of data of Braune, et al., including the molecular aggregation of S_4. As Gamson and Elkins pointed out, these new data yield substantially the same results as presented in their Figure 5. However, the fugacity and other thermodynamic functions cannot be calculated directly from the observed P.V.T. data as McCartney has stated. The reason for this is as follows:

If the sulfur system is considered to be always atomic sulfur, as McCartney has proposed, or diatomic sulfur, the peculiar P.V.T. relationship is due then to extreme deviation from ideality. Existing data (*1, 2, 3*) are carried out only to approximately .01 atm. of sulfur pressure. The molecular aggregation, even at this low absolute pressure and at low temperatures, which are of greatest importance in the design of sulfur-recovery systems because this is where the catalytic end operates, still corresponds to approximately 6 to 8 atoms of sulfur per mole. Some means for adequately extrapolating to zero pressure the excellent data of Braune, et al. are required in order to calculate the fugacity. The experimental data because of this extreme nonideality cannot be extrapolated. Rigorous thermodynamic means for carrying out such calculations are required. This can be done only from the previously derived free-energy equations, relating the equilibrium between the individual specie as done by K. K. Kelly for the data of Preuner and Schupp or as done by Braune, et al. for their own data.

It must be noted that even at pressures as low as 10^{-4} atm. and at low temperatures, S_8 and S_6 are the prime species. Accordingly, what must be done is to use simple, elegant, ideal gas-law relationships to calculate fugacity coefficients at pressures so low that the entire fugacity relationship when predicated upon S_1 or S_2 complicates subsequent calculations. In fact, fugacity coefficients calculated in this fashion give approximately zero values even at pressures as low as 10^{-4} atm.

The difficulty of adequately expressing the lower limit in the calculation of fugacities is enormous and leads to these anomalous results for fugacity coefficients. This is due simply to the fact that the compressibility factor Z in the equation

$$\ln \frac{f}{p} = \int_0^p \frac{(Z-1)}{p} dP$$

for the fugacity coefficient at all measured P.V.T. values and at low temperatures is very close to 1/7 to 1/8 when based on S_1. This compressibility factor Z is not, as McCartney has stated, the reciprocal of the X of the Gamson and Elkins' article but it is the reciprocal of their e.

In conclusion, it may therefore be stated that:

1. The simplest, most direct and accurate method of calculating sulfur-gas equilibrium problems is to utilize the technique described by Gamson and Elkins in their article based upon the derived free-energy equations from the Braune, et al. data. This is done by using the ideal gas-law relationships between the molecular species which gives a straightforward, accurate agreement with all the measured P.V.T. data available to date.

2. The method utilized by McCartney in his paper and oral presentation follows the use of a correct thermodynamic equilibrium constant calculated by means of Equation (24) of the Gamson and Elkins' article, but it is incorrectly used according to Equation (22) of the same article.

3. The proposal by McCartney that fugacity be calculated directly from the P.V.T. data is impossible without first going to derived thermodynamic functions between the molecular species. Such calculated fugacity coefficients indicate extreme deviation from ideality at low temperatures and at pressures approaching even infinite attenuation. Accordingly, it does not appear justified to use a system of calculation where nonideality exists at such low pressures, and that instead the recommendation of Conclusion 1 should be employed.

Table 1

Total Sulfur Pressure in atmospheres	Total Pressure = 1 atm.		Total Pressure = 2 atm.	
	T = 600 °K.	800 °K.	600 °K.	800 °K.
From				
Equation 27	.0409	.0583	.0817	.1026
Equation 26	.0193	.0336	.0395	.0475

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2. Klemm, W., and H. Kilian, Z. *Physic Chem.*, **49B**, 279 (1941).
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effect of load and pressure on performance of a commercial bubble-tray fractionating column

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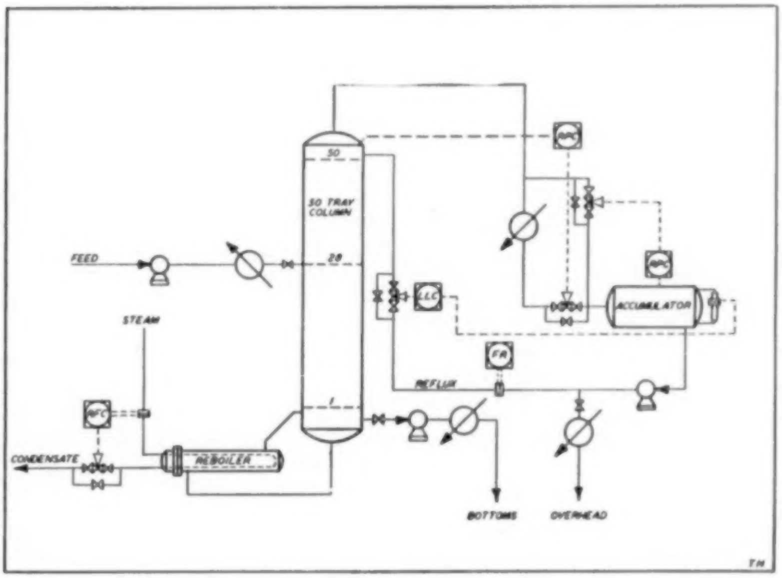

Fig. 1. Flow diagram of experimental column.

Although bubble-tray fractionating columns have been in use for a long time, surprisingly little data are available on certain features of bubble-tray design and operation. In order to supplement the available data on fractionating columns, a series of tests was made on a commercial bubble-tray column.

The experimental data were used in the calculation of the optimum pressure for operation of a column separating isobutane and normal butane. For any separation the optimum pressure is dependent on the number of trays in the column, the desired separation, and the key components. The existence of an optimum pressure which will allow the maximum production of products of a given purity is a result of at least three fundamental factors. These are (1) The capacity of the column increases as the pressure is increased (up to a moderately high pressure), (2) The relative volatility of key components decreases as the pressure is increased, and (3) The number of equilibrium steps per tray increases as the pressure is increased.

A calculation of the number of equilibrium steps requires that the relative volatility be known for the key components of the mixture. A rigorous solution is usually possible only with a binary mixture. (In a multicomponent system the number of equilibrium steps per tray determined from different components will not be the same for the same trays.) However, in most calculations where the number of trays is of prime importance, the material handled consists, in effect, of only two components.

After the equilibrium steps have been calculated for a given separation, the number of trays required may be found by dividing the number of equilibrium steps by the number of equilibrium steps per tray. Usually in design an arbitrary figure is taken for this factor. However, if data are available on columns of similar design handling similar materials, it may be possible to use these data in place of an arbitrary figure.

This study of design factors was undertaken to supplement and improve the present design data for bubble-tray fractionators. Since a commercial fractionating column was used for these studies, only those factors which could be studied without any mechanical changes in design were included. The principal factors included (1) the effect of pressure on column capacity, (2) the effect of load on average number of equilibrium steps per tray, and (3) the effect of pressure and temperature on average number of equilibrium steps per tray.

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Equipment

Experimental studies were made on a 50-tray column, 3 ft. in diam. The trays are of the cross-flow type with 24-in. spacing. A flow diagram of the column is shown in Figure 1. The tray layout and bubble-cap details are shown in Figure 2 and Figure 3 respectively. Additional design data for the column are given in Table 1.

Vapor and liquid sample connections are located at four-tray intervals. Pressure gauges, which were dead weight tested before use, were connected to vapor sample points.

Two Pyrex windows, 4-in. I.D., on opposite sides of the column are located about half way between the 40th and 41st trays (numbered from the bottom). A light source and reflector were

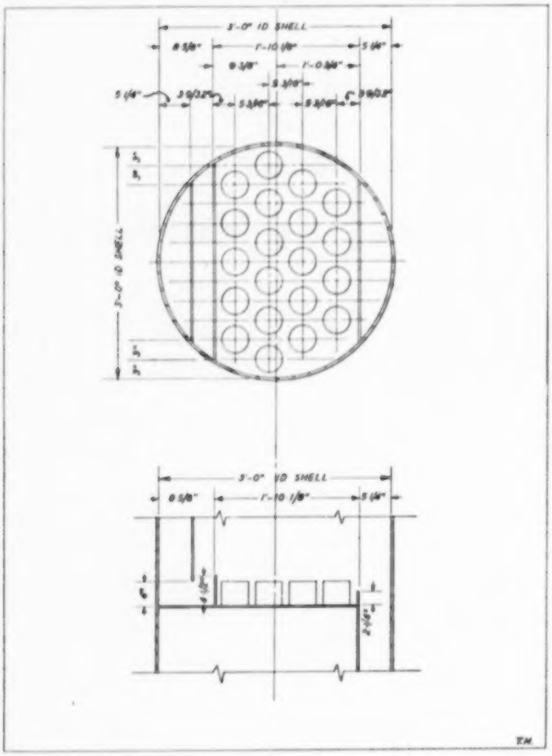

Fig. 2. Tray layout.

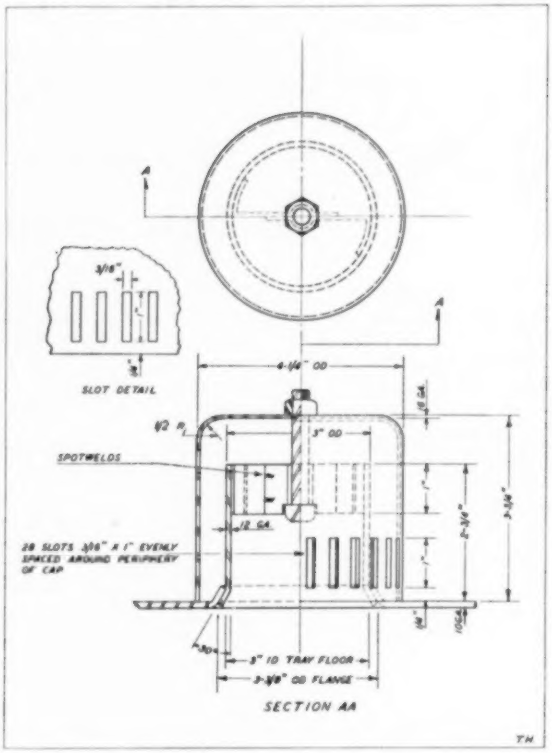

Fig. 3. Bubble cap and riser detail.

mounted outside one window, and the action of fluids on the tray was observed through the other. Most of the 40th tray was visible through these windows.

Experimental Technique

The isobutane-normal butane system was selected since the components are inexpensive, are of similar nature so that behavior of the system should be nearly ideal, have a relative volatility such as to give a measurable concentration gradient throughout a 50-tray column, are easy to analyze, and are key components in commercial separations.

A study of the rate of approach to steady state was made to determine how soon a set of representative samples could be obtained after operating conditions were changed. Analyses were made of periodic samples from a number of trays. For several hours the composition would drift, then become constant within the analytical accuracy. It was found that the composition on a tray where the isobutane content was between 40 and 60% could be followed by periodic sample analyses as a criterion of approach to steady state. The higher analytical accuracy in this concentration region (±0.5%) probably makes this possible. Column survey samples at steady-state conditions were made only after the tray being sampled had maintained a constant composition for a period of at least 2 hr.

The flooding load at total reflux was determined by slowly increasing the steam to the reboiler until the column flooded. Near the flood point these increments represented about one per cent of the flooding load and were not made more frequently than every 2 hr. Flooding was recognized by a rapid loss in reboiler level and a large pressure drop through the column. Data for flooding tests at total reflux are given in Table 2.

After the flooding load had been determined at an operating pressure of 100 lb./sq.in. gauge, column surveys were obtained at about 25, 40, 50, 75, and 90% of the flooding load at 100

Table 1.—Design Data for Experimental Column

Number of trays	50
Tray spacing	2 ft.
Inside diameter	3 ft.
Net cross-sectional area	6.43 sq.ft.
Area of downcomer at tray level	0.64 sq.ft.
Height of downcomer seal weir	4.5 in.
Length of downcomer seal weir	31 in.
Height of tray overflow weir	2.25 in.
Length of tray overflow weir	25 in.
Static downcomer seal	0.5 in.
Number of caps/tray	20
Inside diameter of caps	4.12 in.
Slot area/cap	5.25 sq.in.
Total slot area/tray	0.73 sq.ft.
Outside diameter of risers	3 in.
Total riser area/tray	0.845 sq.ft.
Total cap perimeter/tray	22.2 ft.
Height of top of slot above tray	1.25 in.
Reboiler bundle surface area	460 sq.ft.
Overhead condenser surface area	1036 sq.ft.
Bottom product cooler surface area	411 sq.ft.
Overhead product cooler surface area	103 sq.ft.
Feed preheater surface area	103 sq.ft.
Maximum operating pressure of column	160 lb./sq.in. gauge
Steam pressure available	200 lb./sq.in. gauge
Temperature of available cooling water	70° F.

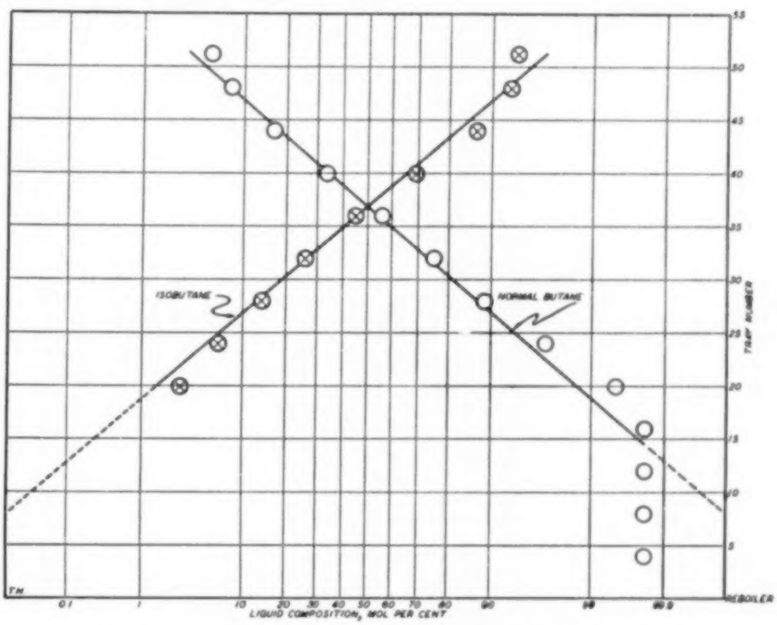

Fig. 4. Concentration gradient for 93.6% of flood at 149.8 lb./sq.in.abs.

lb./sq.in. gauge. These column surveys consisted of a series of liquid samples from reboiler, 4th through 48th trays at four-tray intervals, and reflux, together with pressures at eight-tray intervals, temperatures at four-tray intervals, and temperature, pressure, and flow data on reflux and steam. Flooding loads were also determined at 50 and 140 lb./sq.in. gauge, each being followed by a column survey at 90% of flooding load at these pressures.

Analyses of all samples were made by infrared spectrometry. Analytical values for column survey samples were plotted on arithmetic probability paper for smoothing. As an example, the concentration gradient for 93.6% of flooding load at 149.8 lb./sq.in.abs. is given in Figure 4.

In addition to the tests at total reflux seven flooding tests were made when operating with vapor to liquid ratios other than one (see Table 3).

In addition to the data previously described, the following visual observations were made through the windows on the 40th tray. At 25% of flooding load, considerable priming was observed, the major portion of which appeared to come from one riser. The word priming is used here to indicate passage of liquid downward through the vapor risers. The froth level appeared to be about 8 in. deep, or about 7 in. above the slots. At 50% of flooding load, only slight priming was observed, and the froth level was about 11 in. above the tray. The slight priming observed was all from one riser, which indicates that this particular riser or its cap assembly may have been improperly installed or is defective or corroded. At 75% of flooding load, observation of fluid action on the tray was difficult since the froth level was near or above the top of the window. No priming was apparent, and the froth level was 14 to 15 in. above the tray. At 90% of flooding load the observation windows were covered with froth and the view was completely obscured.

Since no vaporization equilibrium data for the isobutane-normal butane system could be found in the literature, the vaporization equilibrium ratios and the relative volatility were estimated from published fugacity data (*9, 10*) and vapor pressure data (*8*).

The number of equilibrium steps per tray for column surveys at total reflux was determined over three-tray intervals by calculating the number of equilibrium steps necessary to obtain the experimental change in concentration indicated by smoothed curve for the concentration gradient. The number of equilibrium steps was calculated step by step with the vaporization equilibrium ratios estimated from fugacities. A plot of steps vs. concentration was made to determine the number of steps between two concentrations. An average number of equilibrium steps per tray was then computed over that portion of the column below the 48th tray in which the concentration of isobutane was above 5 mole %. Averages were not extended below this point because of the increasing influence of analytical errors. It was more convenient to determine the number of equilibrium steps per tray at total reflux than at an operating condition, since determination at total reflux does not depend on a material balance.

Table 2.—Data for Flooding Tests at Total Reflux 3-ft. diam. column

Date	Time	Column Top Pressure, lb./sq.in.abs.	Column Top Temp. ° F.	Reflux Composition Mole % Isobutane	Reflux Composition Mole % Normal butane	Vapor Leaving Reboiler, lb./hr.
1-13-49	1100	62.3	103.1	82.0	18.0	24,700
1-18-49	1000	64.3	99.0	90.0	10.0	24,400
2- 9-49	0600	72.8	99.5	....	....	27,900
2- 3-49	1930	107.3	125.9	95.9*	3.2*	34,500
2-13-49	1900	109.3	132.0	95.0	5.0	32,150
2-14-49	1130	110.3	130.0	95.0	5.0	32,800
2- 2-49	0400	110.8	130.0	95.0	5.0	36,300
12-30-48	1545	117.3	140.0	82.0	18.0	31,800
12-23-48	2240	118.3	134.0	82.0	18.0	33,650
1-20-49	0600	144.3	153.8	82.0	18.0	35,800
1-20-49	2400	147.3	156.6	82.0	18.0	36,500

* 2.3 mole % propane.

Interpretation of Data

Since the tests were all made on an existing commercial size unit, only certain variables could be investigated.

An attempt was made to obtain the following information

entrainment

1. a comparison of experimental and calculated effects of pressure on capacity.
2. the point in the test column at which flooding first occurred.
3. the effect of liquid load on vapor handling capacity of the column.
4. a comparison of experimental and calculated pressure-drop data.
5. the effect of temperature and pressure on the average number of equilibrium steps per tray.
6. the variation of number of equilibrium steps per tray with vertical position in the column (or concentration).
7. the effect of load on number of equilibrium steps per tray.
8. the calculated optimum operating pressures based on experimental data.
9. the time required to reach a steady state.

This study assumes that the phenomenon which limits column capacity is flooding. Flooding occurs when the pressure drop becomes great enough to cause the fluid level in the downcomer to reach the exit fluid level on the tray above or when the froth level on the tray reaches the tray above,

whichever condition is reached at the lower load. A number of measurements of flooding rates under total reflux conditions have been made at pressures ranging from 60 to 150 lb./sq.in.abs. These are given in Table 2 and as Curve (5) in Figure 5.

In addition to Curve (5), which shows the effect of pressure on flooding load, Figure 5 also includes the effect of pressure on the capacity of the test column as calculated by several conventional methods and a curve representing 90% of the experimentally determined flooding load (Curve 4). A popular method of calculating the capacity of a fractionating column is the method of Souders and Brown (*11*) which is given as

$$W = C[d_2(d_1 - d_2)]^{1/2}$$

where

W = mass velocity, lb/(sq.ft.)(hr.)
C = a factor depending on conditions
d_1 = density of liquid, lb./cu.ft.
d_2 = density of vapor, lb./cu.ft.

The factor C is dependent on the tray spacing, type of service, and surface tension. Two curves for different surface tensions are given in the original

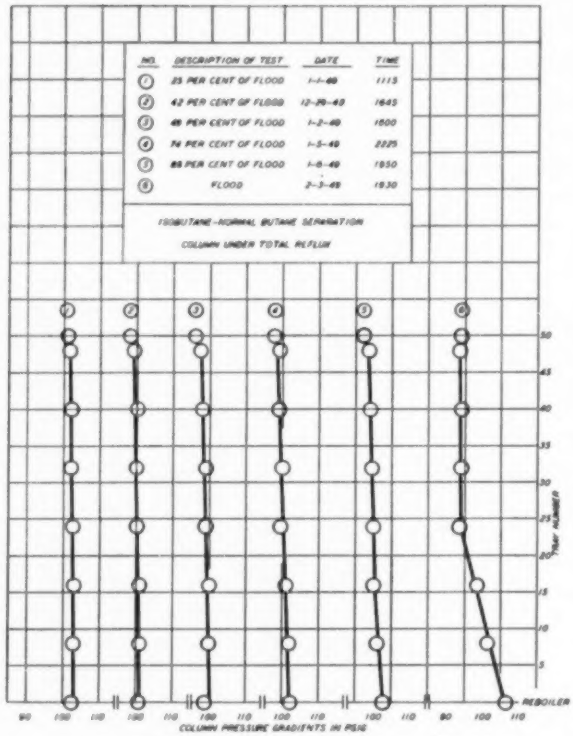

Fig. 6. Effect of loading on column pressure gradient.

article, one for 10 dynes/cm. and one for 20 dynes/cm. By using the 10 dynes/cm. curve (C of 563 for 24-in. tray spacing) to calculate the effect of pressure on capacity, one can find Curve (2) as the result in Figure 5. If this C factor is corrected further by multiplying by 1.2 on the assumption that isobutane-normal butane separation is comparable to a stabilizer, then a curve approximating 90% of the experimental flooding curve (Curve 4) results, which is probably the best interpretation of the Souders and Brown method. In a more recent publication Brown (*1*) presents the same method except that a family of five curves for different surface tensions is given for determination of the factor C. If the effect of pressure on capacity is calculated by this method (interpolating to obtain effect of surface tension on C), then Curve 1 results. It should be noted that the shape of Curve 2 is the same as the experimental flooding curves, but that Curve 2 gives values of about 75% of flooding load (Curve 5). In calculating the column cross-sectional area from W the mass velocity, the total area was used. It was first thought that the net cross-sectional area would be appropriate since the Souders and Brown relationship is based on suspension of droplets of liquid by free-flowing vapor; however, in the discussion of a paper by Brown and Lockhart (*2*) it

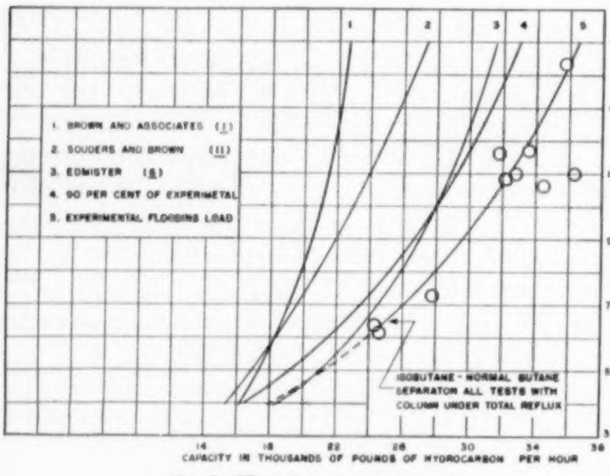

Fig. 5. Effect of pressure on capacity.

Table 3.—Flooding Tests at Various Liquid-Vapor Ratios 3-ft. diam. column

Date	Time	Column Top Pressure lb./sq.in.abs.	Liquid to Reboiler, lb./hr.	Vapor from Reboiler, lb./hr.	L/V Ratio
2-25-49	1520	110.3	52,303	32,260	1.621
2-17-49	2130	109.3	40,750	30,800	1.323
2-18-49	0600	109.8	35,120	28,300	1.241
2-24-49	0100	109.8	35,315	29,410	1.200
2-24-49	0245	110.3	35,335	29,450	1.200
2-17-49	1530	109.8	35,870	30,060	1.194
*	*	109.8	32,400	32,400	1.000
2-27-49	2035	107.8	22,055	34,405	0.641

* From flooding curve at total reflux.

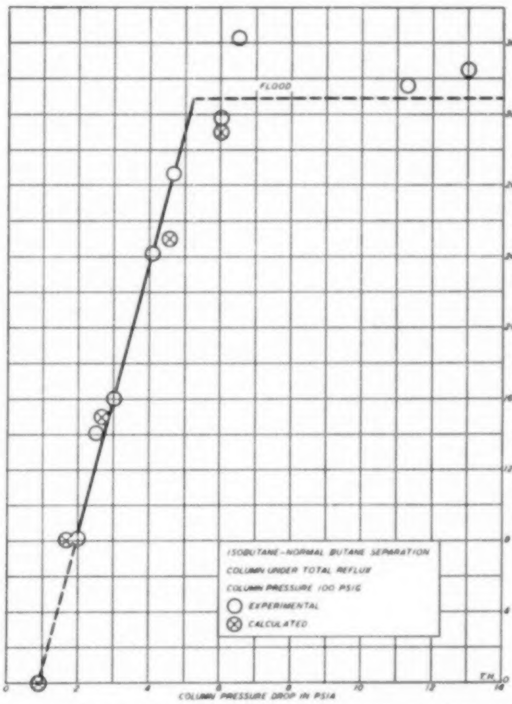

Fig. 7. Effect of loading on column pressure drop.

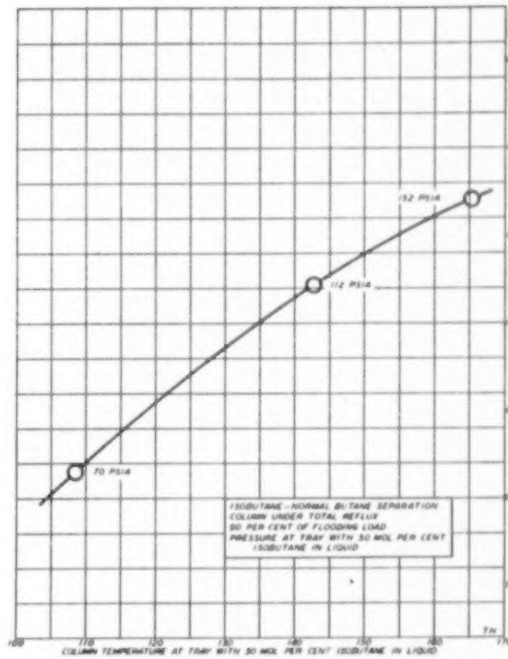

Fig. 8. Effect of temperature on number of equilibrium steps per tray.

was pointed out that the total cross-sectional area was used in the original correlation. Neither the original article by Souders and Brown (*11*) nor the later book by Brown and Associates (*1*) specifically states whether the net or total cross-sectional area should be used. For the test column the net area is 91% of the total area, since 9% of the area is occupied by the downcomer. If it is assumed that 90% of flooding load is a safe operating capacity, then the capacity determined by the Souders and Brown method with the 1.2 factor is satisfactory for the isobutane-normal butane system. If flooding in the test column is due to the froth level reaching the tray above, as visual observations would indicate, then the agreement in shape between the Souders and Brown (Curve 2) and the experimental Curves 4 and 5 could be due to the similarity between frothing and entrainment phenomena. Use of the more recent family of curves for various surface tensions does not give as good agreement as the original method for the hydrocarbon system studied.

The Edmister (*6*) method for estimating capacity produces Curve 3 for effect of pressure on capacity with better average agreement with the 90% of flood curve than the others but of the wrong shape, indicating too low a capacity at high pressures and too high a capacity at low pressures. However, Edmister recommended this method only for preliminary design.

If there are no obstructions in a column, it should flood at the point of greatest load. In a column under total reflux the point of greatest load, when the components have similar thermodynamic properties, is at the bottom due to heat loss. The series of pressure gradients at progressively increasing loads (see Figure 6) shows that the flood developed in the bottom of the test column as would be expected.

The question often arises as to whether the liquid or the vapor load is limiting the capacity. The particular column referred to was flooded at liquid-to-vapor ratios of 0.6 to 1.6 without showing any consistent or appreciable effect on the vapor handling capacity of the column (see Table 3). Therefore, the conclusion is drawn that the vapor load limits capacity.

The effect of column load on the pressure drop is shown in Figure 7. The pressure drop increases linearly with the load until the flooding point is reached. At the flooding point the pressure drop increases rapidly. If the flooding point is approached very slowly, it is sometimes possible to operate slightly above the average flooding load for a short time.

The pressure drops due to the vapor flow are h_{rc}, the head lost by vapor in contraction and expansion through the

entrainment

vapor risers and caps of a dry plate; h_{ss}, the static submergence of top of slot; and h_o, the head over tray overflow weir. The calculated points on Figure *7* are the sum of these three drops by the method recommended by Edmister (*5*) for calculating the value of h_{rc}. A different approach to the calculation of the pressure drop is given by Dauphine (*4*). In this method the pressure drop through the riser and cap is broken down into three parts: (1) the drop through the riser, (2) the drop due to reversal of direction in the cap, and (3) the drop through the slots. The calculated pressure drop through the cap with the use of this method is 2.62 to 2.69 times as much as the value obtained with Edmister's method. If the Edmister method of calculation is used, the column will flood when the effective liquid level in the downcomers is slightly more than one half of the tray spacing. If the method of Dauphine is used, the downcomer is calculated to be slightly more than three fourths full at the flooding load.

Effects of temperature and pressure on the number of equilibrium steps per tray cannot be separately determined since they are dependent on each other in a two-component system. The aver-

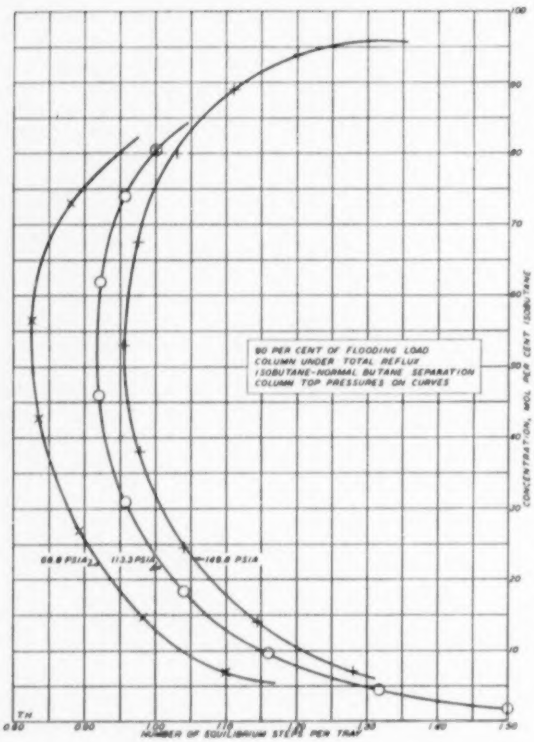

Fig. 9. Concentration vs. number of equilibrium steps per tray.

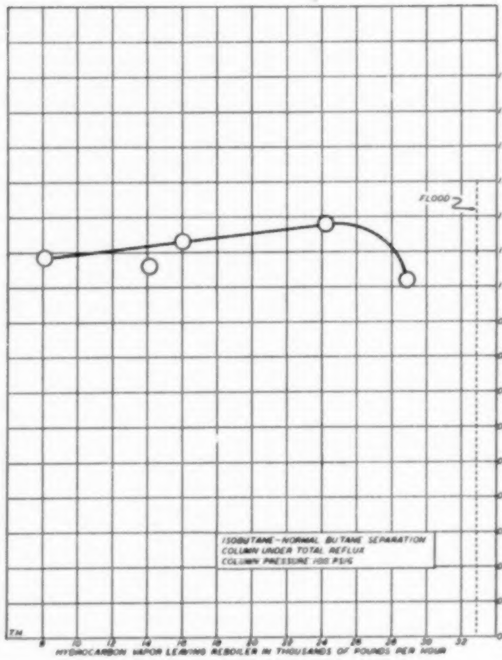

Fig. 10. Effect of loading on number of equilibrium steps per tray.

age number of equilibrium steps per tray is plotted against temperature in Figure 8, with the corresponding pressure for each point indicated.

Figure 9, a plot of concentration vs. number of equilibrium steps per tray for three operating pressures, shows that there is an apparent increase in the number of equilibrium steps per tray near each end of the column. This could be interpreted also as an improvement in the number of equilibrium steps per tray as high purities are approached. Griswold and Stewart (*7*) have reported the same effect and Byman and Keyes (*3*) have reported the opposite effect. The increase in number of equilibrium steps per tray as high purities are approached is probably due to less energy and/or less mass to be transferred under these conditions.

The effect of loading on the number of equilibrium steps per tray is illustrated in Figure 10. Between 25 and 75% of flooding load the number of equilibrium steps per tray increases with load; this is probably due to improved mixing at the higher throughput. Between 75 and 90% of flooding load the number of equilibrium steps per tray falls off rapidly; this is believed to be the effect of increased entrainment.

The existence of a pressure which will allow the maximum production of prod-

Table 4.—Optimum Operating Pressures

Actual Trays in Column	% Recovery: Isobutane in Overhead Product	% Recovery: Normal Butane in Bottom Product	Optimum Column Top Pressure lb./sq.in.abs.	Vapor Load per sq.ft. Cross Section, lb./hr.†	Overhead * Product per sq.ft. Cross Section lb./hr.†	Feed per sq.ft. Cross Section lb./hr.†
30	80.0	80.0	107	4493	842.6	1685
30	90.0	90.0	89	4124	493.2	986.3
30	95.0	95.0	65	3501	280.9	561.7
30	98.36	98.36	60‡	3342	0	0
50	75.4	49.0	139	5006	2837	4489
50	86.8	63.9	132	4905	1320	2148
50	80.0	80.0	122	4751	903.0	1806
50	90.0	90.0	111	4566	638.9	1278
50	95.0	95.0	100	4358	518.4	1037
50	75.18	99.24	100	4358	481.3	1267
50	99.0	99.0	69	3619	295.6	591.3
50	99.85	99.85	60‡	3342	0	0
80	87.6	96.5	132	4905	583.2	1280
80	95.0	95.0	126	4813	592.2	1184
80	97.2	98.8	109	4530	520.1	1057
80	99.0	99.0	101	4379	492.4	985
80	99.997	99.997	60‡	3342	0	0

* Calculated on basis of 50 mole % isobutane and 50 mole % normal butane in feed.
† Based on net cross-sectional area (6.43 sq.ft. for experimental column).
‡ Maximum separation obtainable at total reflux at 60 lb./sq.in.abs. assuming equal recovery of both products.

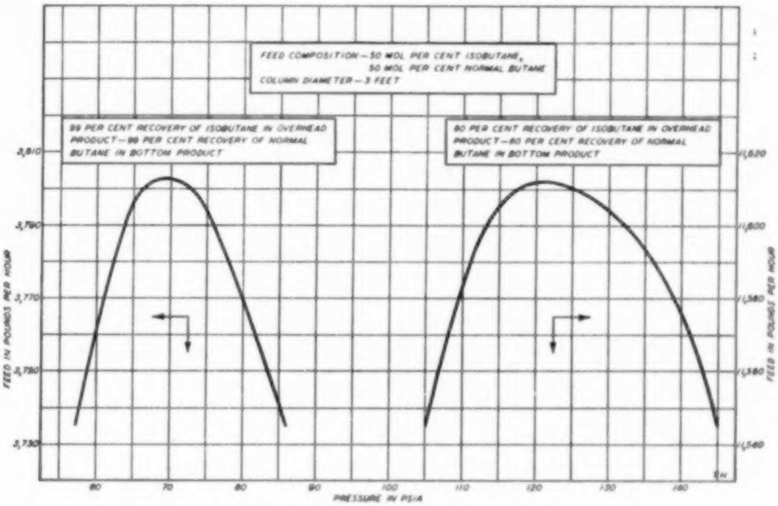

Fig. 11. Production curves for two separations on 50-tray column.

ucts of a given purity or which will permit the maximum amount of feed while recovering a given percentage of the light key component in the overhead product and the heavy key component in the bottom product is the result of at least three fundamental considerations. These are (1) the capacity of the column increases as the pressure is increased (up to a moderately high pressure), (2) the relative volatility decreases as the pressure is increased, causing more reflux to be required for the separation, and (3) the number of equilibrium steps per tray increases as the pressure is increased, permitting the separations to be accomplished with slightly less reflux. This optimum operating pressure is dependent on the number of trays in the column, the desired separation, and the key components being separated.

Sufficient experimental data on a single column are available for the calculation of the optimum operating pressures for the separation of isobutane and normal butane. The results of a series of these calculations are given in Table 4. In making these calculations it was assumed that the average number of equilibrium steps per tray determined under total reflux conditions would be applicable to operating conditions, and that the feed entered the column at the correct tray and with the correct enthalpy. In order to cover the range of column height (number of trays), which are normally used for separations of isobutane and normal butane, calculations were made for 30, 50, and 80-tray columns with the data for the experimental 50-tray column.

The optimum operating pressures given were calculated in the following manner for each separation and number of trays. First with a selected pressure the minimum number of equilibrium steps T_m was calculated step-by-step, and the minimum reflux R_m was calculated from the equation

$$R_m = \frac{x_p - y}{y - x}$$

where x and y are the mole fraction of isobutane in the liquid and vapor respectively at the pinch point—in this case assumed to be the feed tray

x_p is the mole fraction of isobutane in the overhead product.

At a finite reflux R the number of equilibrium steps T was calculated step by step. With the number of equilibrium steps for two or more finite refluxes a curve was established by plotting R_m/R against T_m/T. From this curve the required reflux for the selected pressure was determined from the number of equilibrium steps in the column. The number of equilibrium steps in the column is the number of trays in the column times the number of equilibrium steps per tray at that pressure. Production vs. pressure curves were constructed for several different hypothetical pressures with the procedure just described. The point of maximum production on this curve determines the optimum operating pressure. For the sharper separation the peak in the curve is more clearly defined, consequently, it is more important to operate at the exact optimum pressure for a sharp separation than for a rough separation. This fact is also shown in Table 5 and Figure 11.

An empirical correlation of the optimum pressure data is given in Figure 12. The ordinate is related to the separation, and the curves are for 30, 50, and 80-tray columns. This correlation can be used for a rough approximation of the optimum pressure for any separation of isobutane and normal butane.

The study of the rate of approach to a steady state was made as a preliminary part of the series of tests for the determination of the number of equili-

brium steps per tray. In one test in which the hourly boil-up rate was 1.5 times the column holdup, a period of 18 hr. was required to reach a steady state from the time steam was turned on. This test was run at about 42% of the flooding load.

Application of Information

The information which has been obtained concerning capacity should be useful both for designing new equipment and for estimating what existing columns are capable of handling. Whenever possible, flooding tests should be used to establish safe operating loads. It appears that the Edmister method of estimating capacity is not reliable for all cases (in fact, it is recommended by its author only for preliminary estimates). Until more data on capacity can be obtained, the use of the Souders and Brown method, with a multiplying factor of 1.2 for light hydrocarbons, is recommended. Additional surface-tension correction for this method does not appear necessary. The vapor load rather than the liquid load should be used for determining a column size or for estimating the maximum capacity of a column, unless other considerations indicate downcomer capacity is limiting. A few hydraulic calculations should indi-

Table 5.—Effect of Deviation from Optimum Pressure on Capacity *

% Recovery			% Loss in Capacity			
Isobutane in Overhead Product	Normal Butane in Bottom Product	Optimum Pressure, lb./sq.in.abs.	15 lb./sq.in. below Optimum	15 lb./sq.in. above Optimum	10 lb./sq.in. below Optimum	10 lb./sq.in. above Optimum
80	80	122	0.216	0.196	0.162	0.098
90	90	111	0.536	0.472	0.243	0.236
95	95	100	0.660	0.420	0.285	0.180
99	99	69	2.366	2.420	1.052	0.842

* Calculated for 50-tray column.

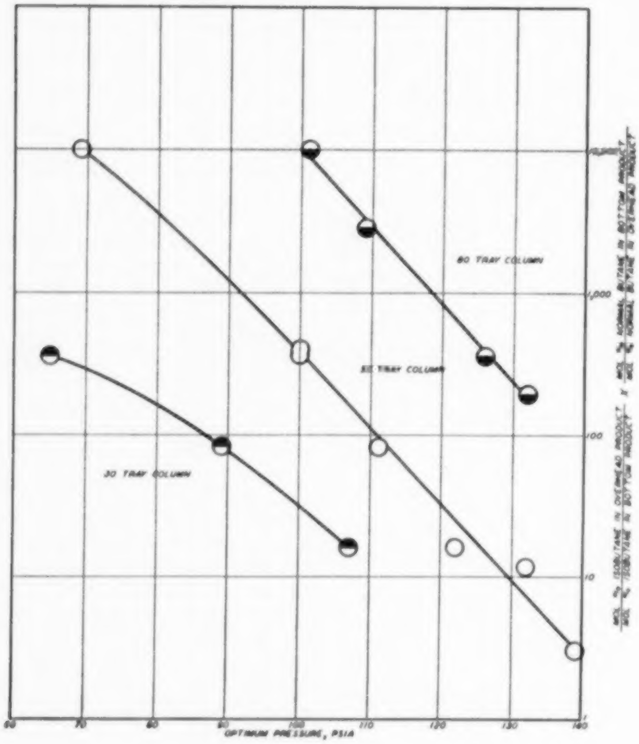

Fig. 12. Correlation of optimum pressure data.

cate if this is the case. The point of maximum vapor load should be used to determine the proper column size. In the test column the capacity could have been increased slightly if its downcomers had been smaller.

As a check on column capacity the pressure drop and the height of liquid in the downcomer at maximum load can be calculated. Since these factors are dependent on tray and column design, they must be evaluated for each column.

The effect of temperature and pressure on the number of equilibrium steps per tray should not be disregarded in the calculation of the optimum operating pressure of a column.

The increase in number of equilibrium steps per tray at very high and very low concentrations is impressive in view of the opposing effect reported for another system (*3*) that tray efficiency approaches zero as pure compounds are approached as end products. It indicates that in removal of trace impurities, where the system properties are similar to the isobutane-normal butane system, additional trays will provide more than the usual calculated separation.

In cases where the number of trays is limiting the purity of a product, there is an advantage in operating at about 75% of the flooding load since the number of effective trays at this load is about 15% greater than at 90% of flooding load.

The economical design of a column for a given separation of isobutane from normal butane is now possible, if the construction and operating costs for small changes in design can be closely estimated.

Operating conditions of existing columns can be compared with calculated optimum operating conditions and the effect of changes in pressure on operating costs can be estimated. A calculation of the optimum pressure of operating columns in which isobutane and normal butane are the key components can be made by assuming that the tray efficiency would be the same as in the test column. The capacity of the column should be determined experimentally for the most accurate estimation of optimum pressure. The presence of propane and lighter or pentane and heavier should not affect the optimum pressure for separation of isobutane from normal butane but will affect the condenser temperature or reboiler temperature required for operation at that pressure. Usually these calculations will indicate how to increase the rate of production and frequently will also point to a saving in steam consumption.

The estimate of the rate of approach to a steady state is useful in estimating how quickly a column may begin making specification product following a shutdown. Also, the rate of approach to a steady state affects the cost of short runs on a column used for intermittent services.

Acknowledgment

The authors wish to thank K. H. Hachmuth for his many helpful suggestions and Phillips Petroleum Co. for permission to publish this paper.

Notation

C = a factor (in Souders-Brown column capacity equation) depending on conditions

d_1 = density of liquid, lb./cu.ft.

d_2 = density of vapor, lb./cu.ft.

L = moles of liquid flowing down column

R = reflux ratio

R_m = minimum reflux ratio

T = number of equilibrium steps

T_m = minimum number of equilibrium steps

V = moles of vapor flowing up the column

W = mass velocity, lb./(sq.ft.)(hr.)

x = mole fraction of light key component (in this case isobutane) in liquid

x_p = mole fraction of light key component (in this case isobutane) in overhead product

y = mole fraction of light key component (in this case isobutane) in vapor

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contents of **nuclear engineering symposium volumes**

"Nuclear Engineering—Parts I, II, and III." Numbers 11, 12, and 13 of Volume 50 of the Chemical Engineering Progress Symposium Series, contain the papers presented at the first international congress on peacetime uses of nuclear energy, held in Ann Arbor, Michigan, in June, 1954, by the American Institute of Chemical Engineers in cooperation with the University of Michigan.

Because space does not permit abstracting such a large number of papers, a list of those appearing in Parts I and II is appended. The papers in Part III will be listed in a forthcoming issue. These three volumes comprise all the papers presented at the meeting except for nine which appeared in the May, 1954, issue of Chemical Engineering Progress. The books may be purchased from Chemical Engineering Progress, 25 West 45 Street, New York 36, New York.

NUCLEAR ENGINEERING—PART I, Chemical Engineering Progress Symposium Series, 50, No. 11 (1954), 280 pp., $3.25 (members), $4.25 (nonmembers).

Synthesis in Nuclear Engineering Education, D. W. McLenegan, General Electric Company

Atomic Energy Jobs for One Engineering Graduate in Ten, Philip N. Powers, Monsanto Chemical Company

Powder Metallurgy of Zirconium and Beryllium, H. H. Hausner and H. B. Michaelson, Sylvania Electric Products, Inc.

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Heat Transfer to Supercritical Water and Other Fluids with Temperature-Dependent Properties, Kurt Goldmann, Nuclear Development Associates, Inc.

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The Temperature Distribution in a Nuclear Reactor Pierced by Circular Cooling Channels, Paul B. Richards, Case Institute of Technology

Use of the Cyclic Heat-Temperature Variation Method for Measurement of Reactor Heat-Transfer Coefficients, S. L. Fawcett and R. E. Grimble, Battelle Memorial Institute

Engineering Problems Pertinent to the Use of Sodium Hydroxide in Reactors, E. M. Simons and J. H. Stang, Battelle Memorial Institute

First Principles of Heat Removal from Nuclear Reactors: The Possible Conflict between Temperature and Power Removal, William A. Loeb, Nuclear Development Associates, Inc.

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Optimizing and Comparing Reactor Designs, F. T. Miles and I. Kaplan, Brookhaven National Laboratory

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The Swedish Reactor, Sigvard Eklund, The Atomic Energy Company, Sweden

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Liquid-Metal-Fuel Reactor Systems for Power, C. Williams and F. T. Miles, Brookhaven National Laboratory

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Gamma-Ray-Initiated Polymerization of Styrene and Methyl Methacrylate, D. S. Ballantine, P. Colombo, A. Glines, and B. Manowitz, Brookhaven National Laboratory

A Thermal Method for Concentrating Heavy Water, E. Cerrai, C. Marchetti, R. Renzoni, L. Roseo, M. Silvestri, and S. Villani, Laboratori C.I.S.E., Italy

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Operational Characteristics of a Heavy-Water Reactor, Arne Lundby, Joint Establishment for Nuclear Energy, Norway

Research Reactor Program at the Pennsylvania State University, William M. Breazeale, Pennsylvania State University

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Application of Analog Computing Techniques to Reactor Dynamic Analysis, J. C. Moise, Pratt and Whitney Aircraft

Application of Analog Computing Techniques to the Solution of Neutron-Flux Distribution Problems, H. C. Honeck and D. G. Ott, Pratt and Whitney Aircraft

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Approximations on the Kinetic Behavior of Fast Reactors, Richard A. Fayram and Karl Bernstein, University of California

The abstracts of papers in "Collected Research—for Spring 1954" will be concluded in a later issue.

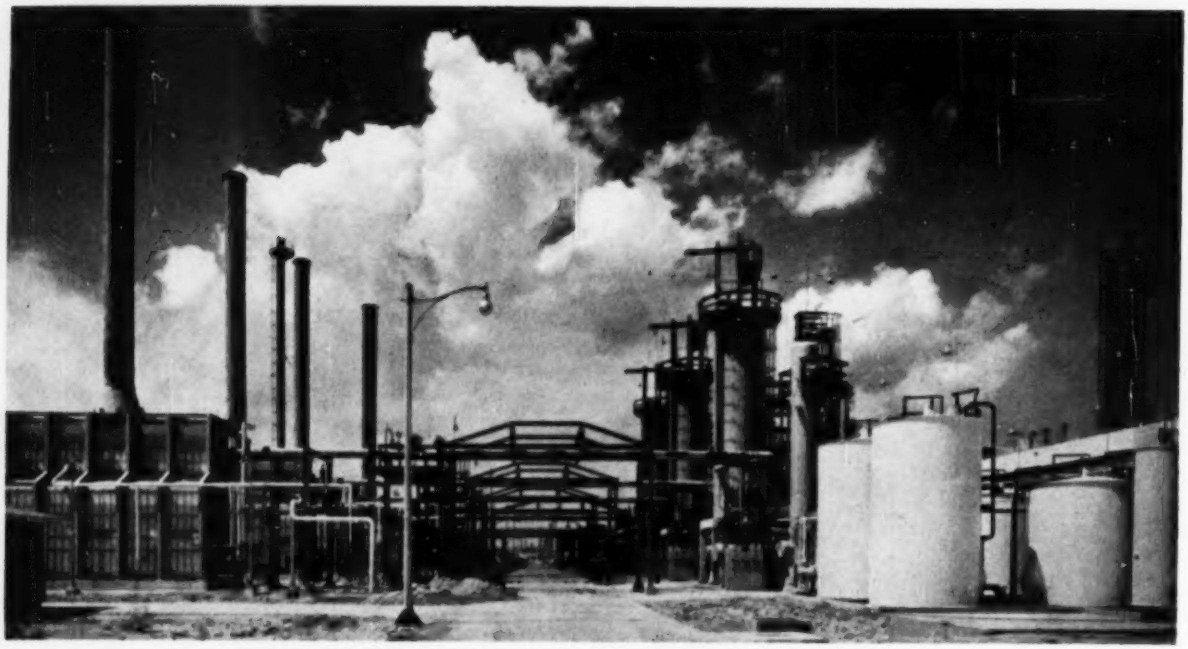

Fig. 5. Shell Chemical Corp., Houston, Texas, ethanol plant, reaction section.

ethanol by hydration of ethylene

C. R. Nelson and M. L. Courter

Shell Development Company, Emeryville, California

Although synthetic ethanol has been produced for nearly twenty-five years and represents a continually increasing fraction of the market requirements, all plants constructed before 1948 used the sulfuric acid ethyl ester process. In this year a Shell Chemical Corporation plant erected at Houston, Texas, used a new process in which a supported acid catalyst replaced the sulfuric acid cycle. The reaction involves hydrating ethylene directly to ethanol rather than processing through ester formation.

Acid in the direct hydration process is used as a catalyst rather than a reactant, and the many problems involved in cycling the sulfuric acid required in the acid absorption process are eliminated. In the sulfuric acid ethyl ester process large quantities of acid are used in high concentration for ethylene absorption and are then diluted for hydrolysis of the esters. The resultant dilute acid must be reconcentrated for recycle. Concentration facilities, which represent a large fraction of the capital investment required for this process, use large quantities of steam with one type of concentrator and with another may create a fume nuisance. Even with proper corrosion-resistant materials, maintenance costs are high in both processing and acid concentrating units. Acid consumption, more important today because of increasing acid prices, is significant, as a large bleed is required to prevent buildup of carbonaceous impurities. In the new process these problems do not exist. There is a resultant decrease in capital investment required, a reduction in maintenance, and either a lowering in utility requirements or avoidance of fume nuisance.

Ethanol has been used for ages and its consumption as a beverage continues unabated, but industrial uses today far surpass potable requirements. The growth curve, Figure 1, is unusual in that, owing to the use of ethanol in the synthetic rubber program during the last war, the curve reached levels not likely to be matched for some time. Since 1930 synthetic ethanol has provided a continually increasing fraction of the total market requirements until it is likely that today synthetic production could supply all industrial requirements. Also shown in Figure 1 are the projected ethanol requirements given in the Paley Report.* These figures give an idea of the probable synthetic ethanol production in the future since it is unlikely that any sizable portion of this market will be supplied by fermentation of molasses or grains. Other syntheses, such as Fischer-Tropsch, may in time supply a large portion of the ethanol market.

Synthesis has replaced fermentation because the price of fermentation alcohol has fluctuated widely over past years owing to variations in the price of molasses, which reached a high of 37¢/gal. Because 2.5 gal. of molasses are required for 1 gal. of ethanol, molasses prices in the higher range are prohibitive for

* The President's Materials Policy Committee, "Resources for Freedom," Volume IV, 1952.

fermentation feed. When Cuba, the principal exporter of molasses, has been unable to dispose of its crop, the price has fallen below 4¢/gal.

Petrochemicals (ethanol from ethylene is an example) have stable raw material costs, an important advantage; however, the synthetic product has other competition than fermentation ethanol. The relatively rapid growth of the use of ethanol has been exceeded by that of methanol and of isopropyl alcohol, Figure 2. Although these two solvents have gained part of the previous market for ethanol, they cannot replace its principal use as a starting material for acetaldehyde. This single usage accounts for approximately 50% of the present ethanol consumption.

The previously mentioned shortcoming of the only commercial synthetic process led process engineers to look for other potential syntheses. Direct hydration possibilities were uncovered but none had been developed for commercialization. Process evaluations of hydration-type reactions were encouraging enough to initiate exploratory studies at the Emeryville Research Center. The process as finally developed is a product of the staff of this center. Comparison of the chosen process with the existing process gave assurance that a new, economically superior process had been developed.

The direct hydration process was first applied commercially by Shell Chemical at Houston in 1948, when a plant was put into operation with a capacity of 20 million gal. of 95% ethanol annually. Later a second unit with a smaller capacity was installed at Grangemouth, Scotland, by British Petroleum Chemicals, Ltd., and was started up in 1951. This licensee examined available synthetic processes and chose the Shell process after observation of initial plant operation at Houston and comparison of process economics. The company is licensed under British Patent 651,275; the equivalent patent here is U.S. 2,579,601. Both the Houston and Grangemouth plants have operated successfully since they have been put on stream.

The Grangemouth plant, the first synthetic ethanol plant in Great Britain, is the largest in Europe. The same factors which have caused rapid growth of petrochemical operations in the U.S. are now effecting a similar activity in Europe, and this plant is a typical example.

During the development of the process the hydration reaction was investigated under widely different conditions, both as to phase relationships and catalysts before a final process choice was made.

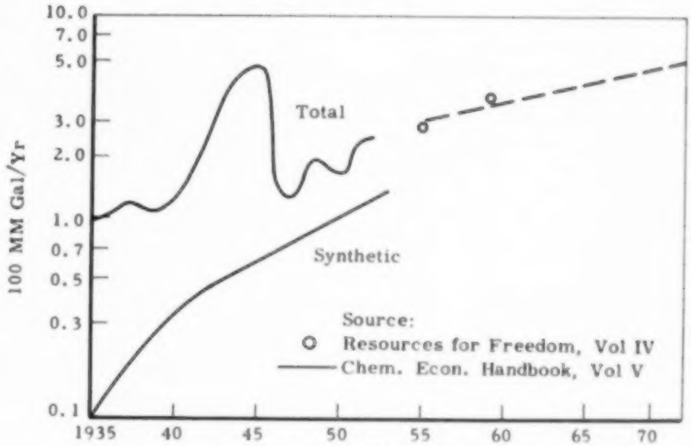

Fig. 1. Ethanol production.

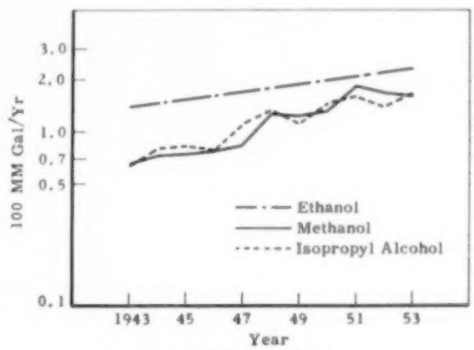

Fig. 2. Alcohol production.

Reactions

In the Shell Hydration Process ethylene and water in the vapor phase are chemically combined over a phosphoric acid-on-Celite catalyst to produce ethyl alcohol:

$$C_2H_4 + H_2O \xrightarrow{H_3PO_4} C_2H_5OH + 19{,}000 \text{ B.t.u./lb. mole}$$

Small amounts of by-products are formed in other reactions, the primary side reaction being the dehydration of ethyl alcohol to form diethyl ether:

$$2\ C_2H_5OH \xrightarrow{\text{Catalyst}} (C_2H_5)_2O + H_2O$$

Acetylene, present as an impurity in the feed ethylene, forms acetaldehyde:

$$C_2H_2 + H_2O \xrightarrow{\text{Catalyst}} CH_3CHO$$

In addition, a small amount of ethylene polymerizes to form less than 1% of a wide range of olefinic polymers.

The product from the hydration reaction is then hydrogenated in the vapor phase over a nickel catalyst. Acetaldehyde is converted in this way to ethyl alcohol:

$$CH_3CHO + H_2 \rightarrow C_2H_5OH$$

In the hydrogenation reaction other aldehydes are converted to the corresponding saturated alcohols, which are readily separated from the ethyl alcohol product. For example, traces of crotonaldehyde are converted to normal butyl alcohol:

$$CH_3{-}CH{=}CH{-}CHO + H_2 \rightarrow$$
$$CH_3{-}CH_2{-}CH_2{-}CH_2OH$$

Process Description

The process flow is shown in Figures 3 and 4. The reaction section of the ethanol plant consists of several parallel units, one of which will be described. The ethylene stream at intermediate pressure is supplied from an olefin preparation unit and charged to the reactor feed compressor, where it is brought to a reaction pressure of approximately 1,000 lb./sq.in. before being charged to the larger recycle stream leaving the recycle gas compressor. The combined ethylene stream is then joined by a stream of water in a ratio of 0.6 moles of water per mole of ethylene. The mixture of ethylene and water at a temperature of 180° F. and 1,000 lb./sq.in. constitutes the total feed to the reactor. The reactor feed stream is preheated by exchange with the reactor product in two exchangers in series. After this heat exchange, the stream is totally vaporized and heated to a final temperature of 570° F. by means of a gas-fired furnace before entering the reactor.

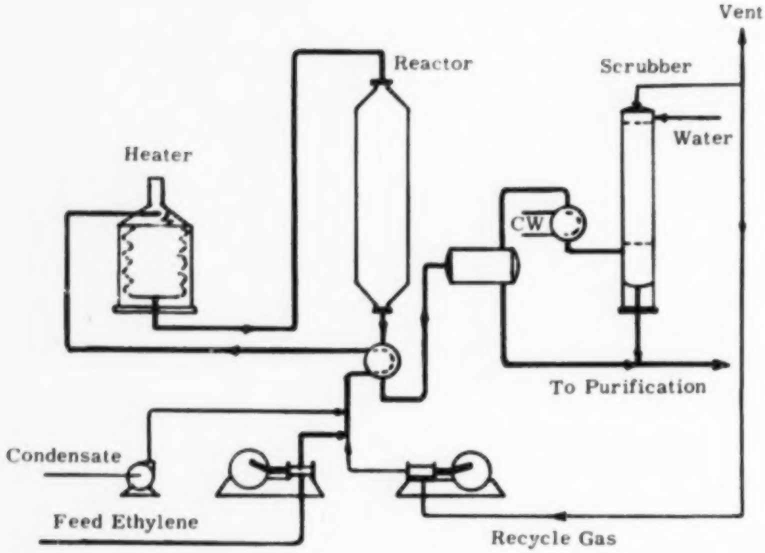

Fig. 3. Process flow—reaction section.

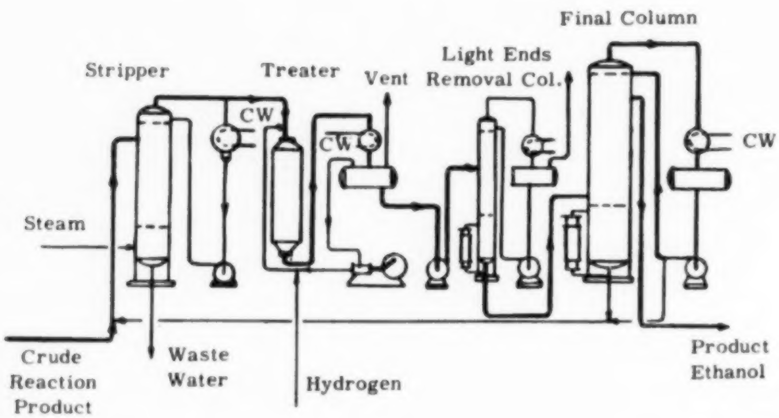

Fig. 4. Process flow—purification section.

The feed enters the top of the reactor and passes downward through the catalyst bed. The catalyst employed is phosphoric acid on a support, Celite, a diatomaceous earth which will be discussed more fully later. A fraction of the ethylene and water is converted to ethyl alcohol on each pass through the reactor. The reaction being exothermic, products leave the reactor at a slightly higher temperature.

The reactor product is directed to the first of the two heat exchangers used in feed-product exchange, where it is partially condensed. After the product leaves this exchanger, a stream of dilute caustic soda is added to neutralize the traces of phosphoric acid carried from the reactor in the product vapor stream. Additional water and ethyl alcohol are condensed from the neutralized product in the second of the feed-product exchangers and the mixture from the exchanger is separated into liquid and vapor in a high-pressure separator. The vapor stream from this separator is then cooled by the recycle gas cooler. The remaining gas is scrubbed with water in a column to remove the alcohol from the recycle gas. A small stream of the recycle gas is removed at this point and returned to the olefin preparation plant to limit the concentration of methane and ethane contained in the reactor feed. Condensate from the recycle gas cooler is combined with that from the scrubber in the lower section of this vessel, where surge capacity is available. The dilute ethyl alcohol from this surge, along with that from the high-pressure separator, is joined with similar streams from the parallel units and directed to a low-pressure separator.

The dilute crude product is pumped from the low-pressure separator to the stripping column in which the ethyl alcohol is concentrated. Water is removed as a bottom product and the concentrated ethyl alcohol is taken overhead. A portion of the overhead product is condensed and returned as reflux and the balance is charged directly to the hydrogenation reactor. A recycled hydrogen stream is combined with the ethyl alcohol before entering the hydrogenation reactor. The combined stream passes downward through the supported nickel catalyst bed and essentially all of the acetaldehyde together with the higher aldehydes which are present in smaller concentration are converted to their corresponding alcohols. The hydrogenated product is condensed in the product exchanger and then separated in a product accumulator from which

the excess hydrogen is recycled to the reactors by a hydrogen recycle compressor. A small stream of make-up hydrogen is added at this point. The liquid hydrogenated product is then sent to intermediate storage.

This intermediate product is next pumped to the light ends column, where light by-products, principally diethyl ether, are taken overhead. Little by-product diethyl ether is formed, but if its recovery for sale is desired, it may be water-washed in a small packed column for removal of the ethyl alcohol in this overhead stream. The bottom product, consisting of ethyl alcohol and water, is pumped to the final purification column, from which the ethyl alcohol product is taken off a few trays below the top of the column. Small amounts of impurities are removed by means of the pasteurization section at the top of the column. The top product is condensed and returned as reflux except for a small stream which is returned to the stripping column, because it consists largely of ethyl alcohol. The bottom product from this column is also recycled to the stripping column for recovery of ethyl alcohol. The product is analyzed as it leaves the final purification column, and if it meets specifications is sent to one of three product receivers. Specification product from the receiver tanks is pumped to final storage.

Figure 5 shows the Houston ethanol plant of Shell Chemical Corporation with the reactors

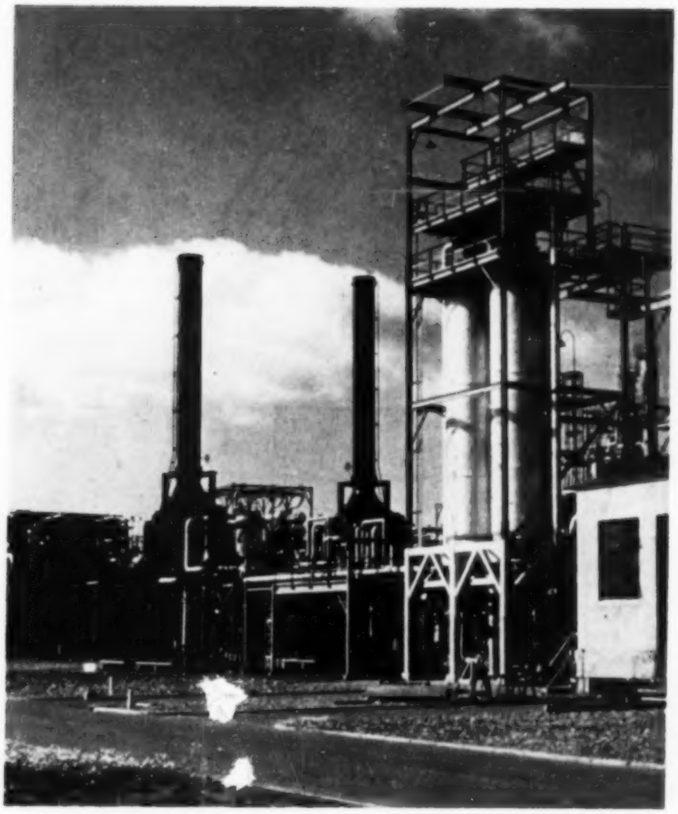

Fig. 6. Reaction section, British Petroleum Chemicals Ethanol Plant, Grangemouth, Scotland.

and furnaces in the foreground. A photograph of the reaction section of the ethanol plant of British Petroleum Chemicals, Ltd., shown in Figure 6, has the two reactors and the compressor house in the foreground. Figure 7 is a view of the finishing section with the three purification columns and product storage tanks.

Design Basis

The conditions used in the ethylene hydration reaction are as follows:

Reaction temperature ...	570° F.
Reaction pressure	1,000 lb./sq.in. gauge
Reactor feed concentration, water-free basis..	85%
Ethylene make-up concentration	97%
Water-to-ethylene molal ratio in feed	0.6
Space velocity, VSVM .. (volumes of gas at 60° F. and 1 atm./min./vol. catalyst)	30
Ethylene conversion per pass	4.2%
Water conversion	7.0%

This reaction may best be visualized if one considers that the catalyst, in this case phosphoric acid, is held by a spongelike support. This support or carrier may contribute certain catalytic properties, but such an interpretation is not

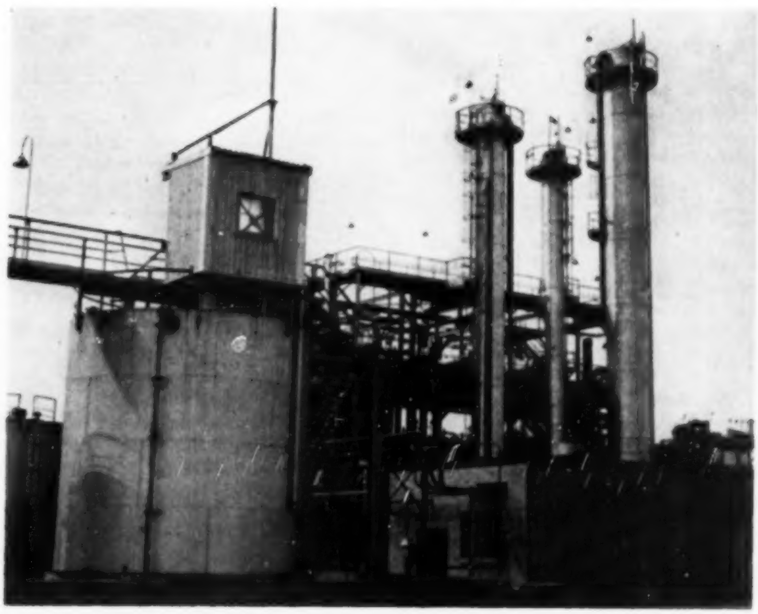

Fig. 7. Purification column and storage. British Petroleum Chemicals Ethanol Plant, Grangemouth, Scotland.

necessary for the visualization of the operation. Most important, the support must have sufficient pore volume to hold relatively large quantities of phosphoric acid and be sufficiently resistant to corrosion under the high temperature and acid conditions existing in the reactor to remain physically strong. Celite, a calcined and pelleted diatomaceous earth, has been found to be a superior catalyst support. A typical composition of this material following calcining is:

Silica	87.0
Iron Oxide	2.2
Alumina	7.5
Magnesia	1.2
Sodium Oxide	1.2
Calcium Oxide	0.6
Titanium Dioxide	0.2
Remainder	0.1

Design Discussion

A change in the pressure, temperature, or water-to-ethylene mole ratio changes in turn the concentration of the phosphoric acid supported in the reactor. The relationship between these variables is indicated in Figure 8. Although the data represented are in the presence of the carrier, they exhibit the characteristic vapor-pressure relationship of aqueous phosphoric acid and are in agreement with the extrapolated data from the literature. As the concentration of phosphoric acid at a given temperature increases, the catalytic activity of the acid also increases.

The equilibrium constant for the reaction of ethylene plus water to ethyl alcohol is shown in Figure 9. As may be computed from the data, the equilibrium concentration of ethyl alcohol decreases rapidly with an increase in temperature; however, as indicated above, when all other conditions are held constant the activity of the catalyst increases with a rise in temperature. Accordingly, there is an optimum temperature where rate and equilibrium taken together lead to a maximum production of ethanol, Figure 10.

For the catalyst used in experimental work under the conditions of operation by which this curve was achieved, a maximum production was accomplished at approximately 570° F. at a space velocity of 28 VSVM, whereas the ethanol production was maximized at approximately 590° F. at a space velocity of 54 VSVM. At lower space velocities for this catalyst the maximum conversion per pass would be achieved at a lower temperature. Catalysts of higher activity may also be utilized in the system. The conditions of operation for such catalysts are selected on a basis similar to that indicated above. A higher activity catalyst at the same space velocity would be operated at a lower temperature. Examination of such a catalyst at the same temperature and perhaps even at the same space velocity might lead to erroneous conclusions as to the total increase achievable.

Since the reactor volume increases with the reduction in space velocity whereas the ethanol production per pass increases with a corresponding change in space velocity, an economic balance may be made between the incremental reactor cost and the incremental requirements for the balance of the plant.

Equilibrium is favored by an increase in pressure; however, an increase in pressure, with all other conditions remaining constant, decreases the concentration of acid on the catalyst and correspondingly decreases the catalytic activity of this material. The decreases may be compensated for by decreasing the mole ratio of water-to-ethylene and/or by changing space velocity until a new maximum for ethanol production per pass is reached. Here again, an economic balance must be made with consideration for the fact that capital investment for specific equipment will

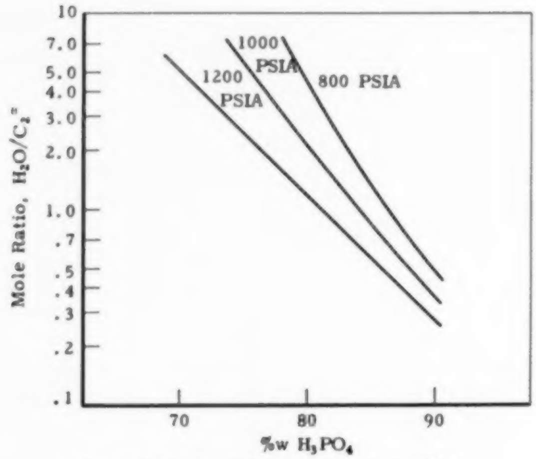

Fig. 8. Acid concentration on catalyst at 585° F.

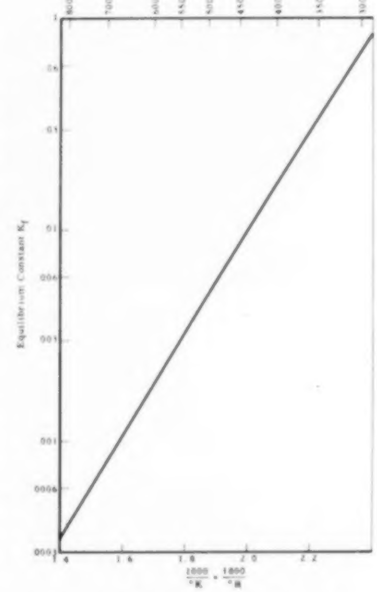

Fig. 9. Equilibrium constant for the reaction. $C_2H_4 + H_2O \rightleftharpoons C_2H_5OH$

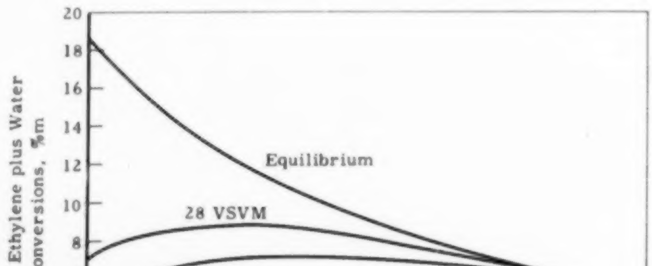

Fig. 10. Effect of temperature on ethylene hydration.

increase with increased pressure rating. Optimum pressure was found to be 1,000 lb./sq.in. gauge.

The ethylene purity in the recycle stream is a function of the feed ethylene purity and the vent rate from the system. The design presented is based on 97% ethylene as make-up and a recycle ethylene purity of 85% is maintained. This again is an economic balance between the size of the ethanol reaction system and the fractionation facilities utilized for the preparation of the purified ethylene. The ethylene feed may be of lower purity, but this will require processing a larger vent stream for a given ethylene concentration in the recycle gas and a fixed reactor pressure. The concentration of ethylene in the recycle gas affects the equilibrium ethanol concentration. In order to achieve the required acid concentration on the catalyst, the water-to-ethylene mole ratio must be changed with a change in ethylene concentration of the reactor feed stream.

By-product formation is primarily a function of temperature. At lower temperatures equilibrium favors production of larger quantities of diethyl ether, whereas at high temperatures the rate of production of polymeric compounds and higher alcohols increases. The effects of temperature may be offset partially by variation of water-to-ethylene mole ratio and correspondingly the acid concentration on the catalyst.

During operation of the reactor for extended periods of time there is a gradual depletion of the acid content of the bed. A small amount of acid is carried from the reactor with the product gases and, as outlined above, is subsequently neutralized. Catalytic activity of the bed decreases as this acid is depleted from the system; however in the case of this catalyst it has been proved in practice that the injection of a stream of acid at the inlet to the reactor will maintain catalyst bed activity for extended periods. Accordingly, only infrequently does catalyst bed activity become the limiting factor and thus regulate the frequency of plant turn-around.

The reactors and the first of the two heat exchangers are lined with copper to avoid corrosion, primarily during the original preparation of the catalyst bed. The small amount of acid carried from the reaction unit is neutralized by a small stream of dilute caustic soda as previously described, and the remainder of the reaction system and the purification unit are constructed entirely of steel. The use of steel for most of the process equipment is one of the principal advantages of the direct hydration process over the more widely used acid absorption process.

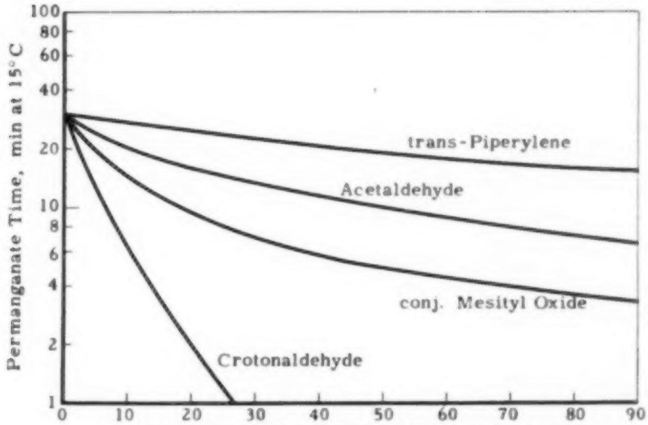

Fig. 11. Effect of impurities on permanganate time.

Product Specifications

The ethanol produced has excellent properties, the purity being 190 proof, or 95% ethanol by volume. Possibly the most important specification for industrial alcohol is the permanganate time test, which is used to indicate the presence of reducing substances. This empirical test varies, depending on the exact procedure followed, but the finished product obtained in this plant exceeds a permanganate time of 30 min. as determined by one of the more exacting test procedures.

Figure 11 shows the effect of certain impurities on the permanganate time which may be achieved with ethanol solutions. Concentrations as low as 5 p.p.m. of crotonaldehyde are sufficient to reduce the permanganate time of a 30-min. ethanol sample to approximately 13 min. Acetaldehyde in concentrations of approximately 35 p.p.m. will also reduce the permanganate time of the 30-min. ethanol sample to about 13 min. An ethanol sample with a high permanganate time when blended with one of low permanganate time results in a mixture approaching the lower value. Unsaturated hydrocarbons also contribute to the reduction of permanganate time but have much less effect than unsaturated aldehydes.

process design

The direct hydration process developed at the Emeryville Research Center has met expectations as to both product quality and plant capacity, and in the highly competitive ethanol market of the past few years ability to produce a product of high purity gave great marketing advantages.

To be presented at New York Meeting, Dec. 1954

CORRECTION

In "Kinetics of the Catalytic Cracking of Alkylbenzenes" authored by Rase and Kirk (C.E.P., January, 1954, page 40), the headings of the last two columns of Table 2 are incorrect.

The column headed "PZ" is actually "$\ln PZ$"; the last column is then

"$\log \frac{\ln P_aZ_a}{\ln P_bZ_b}$" instead of "$\log \frac{P_aZ_a}{P_bZ_b}$."

The ordinate of Figure 6 is then

"$\log \frac{\ln P_aZ_a}{\ln P_bZ_b}$" instead of "$\log \frac{P_aZ_a}{P_bZ_b}$."

The authors actually intended to report the values corresponding to the table headings. Though new values would of course change Figure 6, the relative position of the data points will remain the same. The values appearing in the last column of Table 2 are amended as shown in the accompanying table.

Corrections to Table 2

PZ Factors for Catalytic Cracking of Eight Alkylbenzenes

Compound	$\ln \frac{P_aZ_a}{P_bZ_b}$
Ethylbenzene	0
n-propylbenzene	0.45
n-butyl benzene	0.69
n-amyl benzene	
n-hexyl benzene	
n-heptyl benzene	
iso-propylbenzene	2.58
sec-butyl benzene	2.58
sec-amyl benzene	2.60
tert-butyl benzene	2.85
tert-amyl benzene	2.84

CAST HEAT ALLOY REFERENCE SHEET

N. S. MOTT, Chief Chemist and Metallurgist

The Cooper Alloy Foundry Co., Hillside, N. J.

Alloy: Heat Resistant 15% Chromium 35% Nickel Alloy.

Designations: A.C.I. HT; A.S.T.M. A297-49T Grade HT; S.A.E. 70330.

Chemical Analysis: C 0.35-0.75%; Cr 13-17%; Ni 33-37%; Si < 2.5%.

Applications: For carburization and cyclic-heating service. Used for retorts; muffles; hearth plates; lead, cyanide and neutral salt pots; trays and fixtures; resistance grids; belt links.

Machinability: Machines fairly well.

Heat Treatment: Used in "as-cast" condition.

Weldability: May be welded using a type 330 rod. Is extremely sensitive to weld cracking. No heat treatment necessary after welding.

TYPICAL MECHANICAL AND PHYSICAL PROPERTIES

	Room Temperature		1400° F.	1600° F.	1800° F.	2000° F.
	As Cast	Aged *				
Tensile Strength, 1,000 lb./sq.in.	66	88	34.6	18.8	10.8	6
Yield Point, 1,000 lb./sq.in.	44	59	26	15	8.8	
Elongation, %	12	6	14	26	28	
Reduction in Area, %	14	11				
Brinell Hardness	178	197	100	60	40	

* 24 hr. @ 1400° F. furnace cooled.

Charpy Impact (Std. Keyhole ft.-lb.)	4		
Mod. of Elasticity (X10^6 lb./sq.in.)	24		
Density (lb./cu.in.)	0.286		
Melting Point (° F.)	2425		
Specific Heat (B.t.u./(lb.)(° F.)) @ 70° F.	0.11		
Thermal Expansion (x 10^6 in. (in.) (° F.)) ° F.	70-1000	8.9	
	70-1500	9.2	
	70-2000	9.8	
Thermal Conductivity (B.t.u./(hr.) (sq.ft.)(° F/ft.)) ° F.	70-212	7.7	70-1500
	70-1000	11.4	70-2000
Electrical Resistance (microhms/cu.cm.) @ 70° F.	100		

HIGH TEMPERATURE STRENGTH: (lb./sq.in.)	1400° F.	1600° F.	1800° F	2000° F.
Stress Rupture (100 hr.)	17,000	9,000	4,800	2,500
Stress Rupture (1000 hr.)	12,000	7,000	3,750	1,700
Creep (1% 10,000 hr.)	7,700	4,500	2,000	500

MAX. (° F.) TEMPERATURE FOR CORROSION RESISTANCE:

Air Oxidation Resistance	1950
Oxidizing Sulfur Bearing Flue Gas (Low Sulfur)	1950
Oxidizing Sulfur Bearing Flue Gas (High Sulfur)	1800
Reducing Sulfur Bearing Flue Gas (Low Sulfur)	1950
Reducing Sulfur Bearing Flue Gas (High Sulfur)	1750

High Temperature Corrosion Resistance:

Molten drawing and Tempering Salts .... Good

Molten Cyaniding Salts ..... Good

Molten Neutral Salts .... Poor

Molten High Speed Salts..... Fair

Molten Metal Resistance .... Good resistance to molten lead and tin. Poor resistance to Babbitt and no resistance to molten aluminum and magnesium.

Carburization Resistance:

Pack Carburizing .... Good

Gas Carburizing (< 15% CH_4) Excellent

Carburizing in Natural Gas (High CH_4) .... Fair

General High Temperature Characteristics:

This alloy has good high temperature strength and ductility and also is fairly resistant to thermal fatigue cracking. Its resistance to the effects of cyclic heating is good and its hot impact resistance is fairly good. It has poor resistance to sulfur-bearing gases and should not be used under such conditions.

No. 38

PREVIEW

New York Annual Meeting

December 12-15, 1954

the NEW YORK and NEW JERSEY sections

cordially invite you to

NEW YORK, N. Y.

CHEMICAL ENGINEERING CENTER OF THE WORLD

D. A. Levenson | Equitable Paper Bag Co., Long Island City, N. Y.

New York City, center of arts and commerce . . . home of the United Nations . . . site of decision on an design of more chemical process plants than any other city in the world, is an ideal place to come to this winter for both business and pleasure. It will be especially ideal in December when the Institute will be holding its annual meeting—considering as how Institute meetings are so friendly, and how all the facilities of the great city will then be in "high gear!"

There's going to be so much going on in connection with this convention—that it almost defies description. One of the most important things about it will be that all meeting events will take place under one roof—the broad expanse of the Hotel Statler. That is all events except the sight seeing tours, the trip through the big steamship Ile de France, the theater parties to two Broadway hit shows, the taking over of the entire TV studio for the panel show "What's My Line?"—complete with John Daly, Dorothy Kilgallen and other regulars—and so on. In other words, you can take your choice—stay all three and a half days in the hotel if that's the way you want to figure it, or go on out once in awhile with the gang and see a bit of the big glamorous city while you're so close to it all. . . .

On the business side, everyone comes to Institute conventions to meet a lot of other chemical engineers from all over the country. This Institute meeting in New York will give you more opportunity than usual to do just that—and the spacious facilities of the Hotel Statler have been picked just so you can have plenty of room to mosey around, then sit down in a quiet spot and talk shop all you want to without people tripping all over.

Also on the business side of things—if you're the real serious type, you can make more important calls on more people with authority in this city than anywhere else in the country. For a ten cent phone call or a fifteen cent subway ride, you can make contact with a top-staffed office of almost any major

"What's My Line?" popular TV show, will be performed Sunday evening before an audience of chemical engineers!

EIGHT REASONS WHY YOU SHOULD COME TO THIS MEETING:

- Open house at Institute's new headquarters.
- Outstanding technical program—12 sessions, 6 symposia.
- Accessibility to major offices of equipment suppliers, engineering service firms, and process operators.
- World's finest library facilities—conveniently located.
- Hear the Secretary of Commerce, and a member of the A.E.C.
- Enjoy the lavish, yet completely informal and modestly-priced entertainment planned for you and your wife.
- Take in New York—the city that has everything. . . .

process operating firm, engineering service organization or equipment or materials vending company located anywhere in the U.S.A. Or better yet, come on over to the Institute's new office quarters and use the phone—as well as look things over. You can run over to the Chemists' Club Library, or the Engineering Societies Library and do checking up to your heart's content—the missus, incidentally, being occupied with the rest of the girls, on the dozen or so things you couldn't keep her away from with six wild horses.

Young man & the Institute

Growing into management is something a lot of young chemical engineers find themselves doing. Problems naturally arise . . . some of which can best be handled by the individual himself, with a little coaching from his industrial employer. Others seem to call for assistance that might best come from the man's professional society. The Professional Guidance Committee of the Institute has for some time been concerning itself with this matter, and has recently been sponsoring field meetings as a step towards bringing the situation out into the open for constructive consideration and action. Now, plans are being finalized for a Sunday afternoon panel forum on *"Growing into management—how a professional society can help"* to take place 2:00 p.m. December 12th. This will be an open meeting with free discussion and questions from the floor. Young men will be on the panel to describe "growing pains." Representatives will be on hand to discuss what the Institute might do. Industrial management men will be there not only to advise, but also to take back a few ideas for consideration. Whether this forum "clicks" depends on whether you and your friends—regardless of whether you're elder statesman or fledgings—come and take part. Seriously, please plan to be there. . . .

Cocktails, buffet . . . and Rouge

Staying with the course of events as they'll unfold, you'll be going, after the panel session, to an open house cocktail party—which means, drinks will be on the house (Institute)! By this time you'll have organized a bunch group ready to go somewhere for eats—but you won't have to go far—just downstairs to the fabulous Cafe Rouge, where nobody but the Institute gang will be around for an informal buffet supper. Fun? Brother, it'll probably be the only time you'll ever eat so much in a place like that, and do it on the Institute's special flat rate!

TV

All through with Sunday? Not on your life—the fun has just begun. A few minutes, ride with the gang will have you in the TV studio of "What's My Line"—and you can imagine what it's going to be like with an entire audience of chemical engineers. . . .

Monday . . . at last!

If you wake up Monday morning with "that" feeling of it now being time to get-on-the-ball, make a mental note to call room service for one of those Statler breakfasts-in-bed. You'll be in New York—the wonder city—where you can lie back and feel regal, until you darned well want to get up and be about. For wonder of all wonders you won't have to do anything Monday 'til two o'clock in the afternoon, when the technical sessions begin. Of course, the plans were made on the basis that you will want to be up and about, visiting a plant or seeing the sights of the city with some fellows, or if your wife is along (as everyone's wife who reads this will probably be) you'll want to tag along on the trip the gals will be taking (see Ladies' Program). You're invited, by the way, to go along solo—so to speak, if you wish.

Monday afternoon technical sessions

Two sessions will be held simultaneously. One will be on *business organization.* Four outstanding men will show you the why's and wherefore's of management, from principle to practice. The basic principles will first be defined and organizational structures analyzed. Then these principles will be applied to illustrate an actual enterprise where personalities come into play. Finally, you will be shown how the organization is kept going—and hear about how important it is to interpret the organization to the staff, maintain a good communications system, have policy committees, and so on.

The other will be on *gas absorption.* In this symposium, combinations of opera-

Continued on page 36

One of the theatrical selections.

Ladies' Program

Wives—don't let this one pass by. Say "you're going" and make it stick. We're expecting the biggest turnout of ladies ever to attend an Institute meeting, and just to prove it, we've set up a program and made arrangements all along the line to take care of large numbers.

There will be an Institute ladies' lounge in the hotel through which all arrangements for attendance at functions set up primarily for the ladies, will have to be made. This goes for the men too, if they want to take in the events.

These events, in addition to those already described for both husbands and wives (such as the Sunday afternoon panel meeting—girls, be sure to come to this and get in on the ground floor of your husband's professional future), will include the following:

Monday morning: Nine to ten, a coffee get-together . . . . following which there will be a tour through the United Nations (50 limit) with a luncheon in the delegates, dining room . . . . or, a tour through Macy's bureau of standards.

Monday afternoon: Another tour will take visitors through Manhattan including Chinatown, Times Square, Greenwich Village, lower east side, Bowery, Wall Street and the United Nations headquarters.

Tuesday morning: The girls are invited to a breakfast fashion show at B. Altman's famous Fifth Avenue store. Imagine eyeing gorgeous models over a cup of coffee, and coming away with door prizes . . . if you're that lucky!

After the luncheon with the men, there will be an event that should be a super sell-out! It will be a tour of the fabulous ocean liner Ile de France . . . . or, for those more interested in seeing the very ultra in modern skyscrapers, a tour through fantastic Lever House!

On Wednesday morning there will be a repeat tour of the U.N. or Macy's for those who missed the earlier ones. For others, it'll be a wonderful time to count out those last remaining bucks and do a wee bit of shopping—souvenirs for Junior, of course. And now hold on for the grand finale to a wonderful time in New York—the

Wednesday afternoon theater parties!

Your Institute committee has purchased blocks of seats for matinées of two hit shows—"By the Beautiful Sea," the charming musical starring Shirley Booth, and the Pulitzer Prize comedy "Teahouse of the August Moon." Institute theater parties will be made up in the order of receipt of advance payments for tickets. Each group will be limited to 100. See you on Broadway!


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NO TAR
NO GREASE
has the dry fabric seal that
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TO GAS HOLDER
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New York Meeting Preview

(*Continued from page* 34)

tions taking place simultaneously will be the keynote. You'll have an opportunity to hear some of the latest observations about such occurrences as mass transfer between two liquids while a chemical reaction is taking place . . . and so on.

Monday evening will be open for whatever you want to organize with your friends—new and old.

Tuesday morning technical sessions

Solvent extraction symposium will place major emphasis on liquid-liquid extraction, with subjects ranging from systems to a new piece of equipment called a rotating disc contactor. This symposium will be continued over into the afternoon.

Simultaneously, there will be a *general technical session* containing some papers of unusual interest. Take the first one, for example. This will reveal essential details of the Shell process for production of ethanol by hydration of ethylene. You can read this paper in an advance form beginning on page 526 of this issue of C.E.P.—then come to the presentation by the authors with plenty of questions to ask. Also on the program will be papers on use of by-product HCl as a chlorinating agent, and performance of filter media.

Tuesday luncheon—addresed by member of Atomic Energy Commission

Make a mental note right now to take in this luncheon, as it will be a dramatic affair, complete with leaders of industry, education and your Institute. Reason: Celebrating the bi-centennial anniversary of Columbia University.

S.S. Ile de France—great ocean liner to be visited . . .

Tuesday afternoon technical program.

Continuation of the *solvent extraction* symposium will bring forth several papers on the theoretical aspects of extraction plus one on a process for extraction of petroleum fractions with ammonia.

(*Continued on page* 48)

TECHNICAL PROGRAM

New York Meeting

TECHNICAL SESSION No. 1

(Simultaneous with Session No. 2)

SYMPOSIUM ON BUSINESS ORGANIZATION FOR THE CHEMICAL INDUSTRY—THE MEANING OF ORGANIZATION, John R. Sargent, Cresap, McCormick and Paget, New York, N. Y.

ORGANIZATION OF AN ENTERPRISE, Lounsbury Fish, Standard-Vacuum Oil Co., New York, N. Y.

IMPLEMENTING AN ORGANIZATIONAL PLAN, John L. Hammer, Jr., Monsanto Chemical Co., St. Louis, Mo.

TECHNICAL SESSION No. 2

(Simultaneous with Session No. 1)

GAS ABSORPTION SYMPOSIUM, R. L. Pigford, Presiding

MASS TRANSFER BETWEEN TWO LIQUIDS WITH CHEMICAL REACTION, Richard Searle and Kenneth F. Gordon, University of California, Berkeley, Calif.

PLATE EFFICIENCY WITH CHEMICAL REACTION —ABSORPTION OF CO_2 IN MONOETHANOLAMINE SOLUTIONS, Arthur L. Kohl, The Fluor Corp., Los Angeles, Calif.

GAS ABSORPTION AND OXIDATION IN DISPERSED MEDIA, L. B. Andersen and H. F. Johnstone, University of Illinois, Urbana, Ill.

GAS ABSORPTION ACCOMPANIED BY CHEMICAL REACTION, P. V. Danckwerts, Cambridge University, England.

MECHANISM AND ABSORPTION OF CARBON DIOXIDE IN AQUEOUS SOLUTIONS OF MONOETHANOLAMINE, R. E. Emmert and R. L. Pigford, University of Delaware, Newark, Del.

Tuesday, December 14, 1954

TECHNICAL SESSION No. 3

(Simultaneous with Session No. 4)

SOLVENT EXTRACTION SYMPOSIUM, R. B. Beckmann, Presiding.

PERFORATED PLATE EXTRACTION COLUMN—PERFORMANCE AND WETTING CHARACTERISTICS, F. H. Garner, S. R. M. Ellis, J. W. Hill, The University, Edgbaston, Birmingham, England.

EFFICIENCY AND CAPACITY FACTORS IN LUBE EXTRACTION, J. R. Felix and C. H. Holder, Esso Laboratories, Standard Oil Development Co., Linden, N. J.

LIQUID-LIQUID EXTRACTION IN CONTINUOUS-FLOW AGITATED EXTRACTIONS, A. W. Flynn and R. E. Treybal, New York University, New York, N. Y.

THE ROTATING DISC CONTACTOR—A NEW TOOL FOR LIQUID-LIQUID EXTRACTION, G. H. Reman, Koninklijke/Shell Laboratorium, Amsterdam, Holland and R. B. Olney, Shell Development Company, Emeryville, Calif.

MASS TRANSFER IN A HORIZONTAL LIQUID-LIQUID EXTRACTION TUBE, N. F. Murphy, J. E. Lastovica, and A. E. Skrzec, Virginia Polytechnic Institute, Blacksburg, Va.

TECHNICAL SESSION No. 4

(Simultaneous with Session No. 3)

GENERAL PAPERS, W. E. Catterall, Presiding.

ETHANOL BY HYDRATION OF ETHYLENE, Charles R. Nelson and Martin L. Courter, Shell Development Company, Emeryville, Calif.

UTILIZATION OF BY-PRODUCT HYDROGEN CHLORIDE AS CHLORINATING AGENT, Aaron J. Teller, Fenn College, Ceveland, Ohio.

STRUCTURE AND PERFORMANCE OF FILTER MEDIA, H. P. Grace, E. I. duPont deNemours & Company, Wilmington, Del.

TECHNICAL SESSION No. 5

(Simultaneous with Session No. 6)

SOLVENT EXTRACTION SMPOSIUM, R. E. Treybal, Presiding.

ON THE FUNDAMENTALS OF THE HYDRODYNAMIC MECHANISM OF SPLITTING-UP IN DISPERSION PROCESSES, J. O. Hinze, Royal Dutch Shell Laboratory, Delft, Holland.

DISPERSED PHASE HOLD-UP IN PACKED, COUNTERCURRENT LIQUID-LIQUID EXTRACTION COLUMNS, C. E. Wicks and R. B. Beckmann, Carnegie Institute of Technology, Pittsburgh, Pa.

AN ALGEBRAIC APPROACH TO SOLVENT EXTRACTION OF COMPLEX MIXTURES, H. F. Hopp and R. B. Smith, Sinclair Research Laboratories, Inc., Harvey, Ill.

CALCULATION OF LIQUID-LIQUID EQUILIBRIA FOR COMPLEX SOLVENT EXTRACTION SYSTEMS, H. R. Sheely, Stone & Webster Engineering Corp., Badger Process Division, Boston, Mass.

EXTRACTION OF PETROLEUM FRACTIONS BY AMMONIA SOLVENTS, M. R. Fenske, R. H. McCormick, H. Lawroski, and R. G. Geier, Petroleum Refining Laboratory, Pennsylvania State University, State College, Pa.

TECHNICAL SESSION No. 6

(Simultaneous with Sesion No. 5)

GENERAL PAPERS, Walter E. Lobo, Presiding.

POLLUTION ABATEMENT WITHOUT WASTE TREATMENT, C. Fred Gurnham, Michigan State College, East Lansing, Mich.

EFFECTS OF HYDROGEN AT HIGH PRESSURES ON THE MECHANICAL PROPERTIES OF METALS, H. C. Van Ness and B. F. Dodge, Yale University, New Haven, Conn.

CATALYTIC HYDROGENATION OF CARBON MONOXIDE AND DIOXIDE OVER STEEL, Buford D. Smith and Robert R. White, University of Michigan, Ann Arbor, Mich.

EFFECT OF DRYING CONDITIONS ON DRYING RATE AND PHYSICAL PROPERTIES OF A POROUS SOLID, E. H. Lebeis and T. A. Burtis, Houdry Process Corp., Marcus Hook, Pa.

THE TRANSIENT BEHAVIOR OF SINGLE-PHASE NATURAL CIRCULATION LOOP SYSTEMS, C. D. Alstad, H. S. Isbin, N. R. Amundson, University of Minnesota, Minneapolis, Minn.

Wednesday, December 15, 1954

TECHNICAL SESSION No. 7

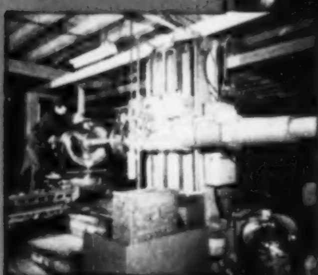
SYMPOSIUM ON NEW PROCESSES UTILIZING FLUID AND MOVING BEDS, Norman Morash, Presiding.

(*Continued on page* 52)

Here in our Tulsa plant, home of Climax Controls, the Product Development Group translates new concepts of automatic control into final engineering drawings for equipment to meet the precise requirements of tomorrow's Process Industries.

Here's Why BS&B CLIMAX CONTROLS give such *Outstanding Performance!*

Many different metals are required in the making of Climax Controls. Sizable stocks of steel bars and tubing are maintained in the plant at all times.



Only the most advanced engineering and design . . . the most modern manufacturing equipment and methods . . . the most exhaustive test procedures . . . and years of practical experience and "know-how" in the industry can combine to produce controls of the quality, precision, long life, efficiency and reliability that you get in Climax! The excellence of BS&B Climax Controls has gained for them a world-wide reputation—for nowhere in the world will you find a better line of automatic process controls...or a company which takes more care and pride in their manufacture! When next you need control equipment for a new installation or for replacement purposes, be sure to specify BS&B Climax . . . you'll be glad you did!

A large investment in highly specialized equipment is required to enable us to manufacture Climax Controls in a full range of types and sizes, from the smallest to the largest.

Our skilled machinists and craftsmen take great pride in their ability to turn out consistently fine quality precision work to the customer's most exacting tolerances.

When required, finished parts are heat treated in these precisely controlled electric annealing furnaces—some of the most modern of their kind anywhere in the world.

To assure maximum on-the-job efficiency, every Climax Control must pass rigorous operating tests in one of the industry's most modern hydraulic and experimental laboratories.

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OVER 60 YEARS
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NATIONAL MEETING REPORT

Glenwood Springs, Colorado. Fall, 1954—Annual resort meeting drew both serious and vacationer from all sections of country. One fourth of registrants were wives (probably an all-time record). . . . Western customs and western chemical engineering operations contributed to making this a broadening and thoroughly enjoyable event. . . . In addition to providing the most exhilarating scenic and recreational atmosphere, this meeting brought out the latest on uranium ore and oil shale processing, agglomeration, and our resources of the future. To all who didn't attend, a hearty invitation to share in the fellowship and interchange of practical information at the next Institute meeting (see New York Preview, page 33, this issue) . . . *Hotel Colorado*—

Sunday arrivals from westbound California Zephyr; note mounted welcoming committee in background.

We enjoyed Glenwood Springs, Colorado

Scenic
Breathtaking views were everywhere about the Glenwood Springs area, which is located in the heart of the Rockies. Pictures to right were taken at elevations of about 12,000 ft.

Square Dance
Tradition of West, it served to bring guests closer together on a "fun and informality"basis. Costumes were the same type as worn for all meeting functions.

Horses & Water
l. to r. Roaring Forks Ranch; J. H. Rushton "aboard"; chemical engineers studying water; "pool duty"—E. Neben in deep meditation.

Fishing
l. to r., The great fishing expedition; audience concentration; the fishermen, with J. H. Rushton, Van, Pres. Kirkbride and Steve Tyler showing most clearly; congratulating Van, who was first to make the catch.

Colorful Canyons. As the path narrowed into its final few miles, dull red walls extending perpendicularly from the road and Colorado River bed indicated the presence of Glenwood Canyon. The setting sun changed reflected hues so rapidly that for fleeting moments picture possibilities would exist—only to fade away before camera adjustment was possible. Nestled in a valley formed by the joining of two major streams (Colorado and Roaring Fork Rivers), emerged the village of Glenwood Springs, with its major landmark, Hotel Colorado. A crispness was in the air . . . enough to provide an invigorating tang for the most weary. Throughout the surrounding village were evidences of folk awaiting their opportunity of serving in Western tradition the last of the summer visitors.

Wranglers All. At the hotel a staff was busily sorting the garb of the traditional west—jeans, form-tight shirts,

(*Continued on page 42*)

Oil from Shale

Now or Later? One of this nation's largest proved reserves of crude oil lies a short distance underground in the form of kerogen locked in layers of shale extending over an area of 1,000 square miles of Colorado, Wyoming and Utah, according to Clyde Berg (Union Oil Co. of Calif.), in his paper presented in W. I. R. Murphy's Symposium on "Oil Shale and Shale Oil Processing." This

(*Continued on page 76*)

authors

l. to r.—Pres. C. G. Kirkbride opening sessions; R. H. Ewell (resources); G. O. G. Lof (gen'l. chairman); J. E. Stepanek (gen'l. technical); W. I. R. Murphy (shale oil); A. P. Weber (agglomeration)

C. H. Prien (shale oil); K. B. Mathur (gen'l. tech.); C. E. Staff (resources); C. H. Chilton (agglomeration); W. R. Thompson (shale oil)

H. E. Rowen (agglomeration); P. L. Cottingham (shale oil); A. C. Byrns (resources); J. D. Moore (uranium); W. W. Hagerty (uranium)

national meeting report

O. C. Ralston (resources); F. A. Brinker (uranium); C. Stirba (gen'l. tech.); C. Berg (shale oil); B. Morris (shale oil)

E. C. Sargent (uranium); M. L. Kastens (resources); C. K. Viland (shale oil); P. D. V. Manning (resources); W. L. Lennemann (uranium); R. L. Philippone (uranium).

(Continued on page 40)

Uranium from Ore

First Data Since 1940. The purpose in bringing the chemical engineer in general up to date on processes for uranium separation, is twofold. On one hand, the methods employed may be improved upon, and with increasing demand for uranium as a fuel, it seems likely that more chemical engineers will be joining those already engaged in this work. Then on the other hand, knowledge of processing techniques involved may be

(Continued on page 76)

Our Future Resources

How Much are We Willing to Pay? There will be no actual physical shortages of materials in the future, stated R. H. Ewell (National Science Foundation) in his symposium "Role of Chemical Technology in Resources for the Future," only greater and greater cost entailed in obtaining those most desired. The net result, for all practical purposes, however, will be economically-based shortages growing in nearly every

(Continued on page 79)

Agglomeration

Old Art Becoming Science? Agglomeration, which means combining of solid particles, is at last beginning to receive deserved attention, according to A. P. Weber (International Engineering), whose symposium was titled "agglomeration."

Fundamentally, agglomeration as it is being studied by chemical engineers, accomplishes predicted and controlled shape and size. Some of the reasons

(Continued on page 81)

—here and there with the C. E. P. camera

l. to r.—Part of group assembled at Climax Molybdenum plant hearing talk by R. Henderson, resident manager; one of the busloads of A.I.Ch.E. visitors to the mine and plant—note ladies; typical meeting scene at hotel.

Mrs. W. B. Wilson, Mr. Wilson, Mrs. R. E. Carver, Mr. Carver; J. F. Olsen, B. K. Duffy; Group at chuck wagon dinner; J. Tielrooy posing with fishing gear at side of pool; Mrs. W. Kelley of local committee caring for daughter of author M. L. Kastens, while father presents paper—evidence of local hospitality!

E. L. Patton, F. C. Bunker, M. Rakchani (from Tehran), C. R. Everett, M. W. Brinker; Mr. & Mrs. W. Kelley; C. Long, W. A. Ackerman, J. C. Dart; Mr. & Mrs. D. Todd.

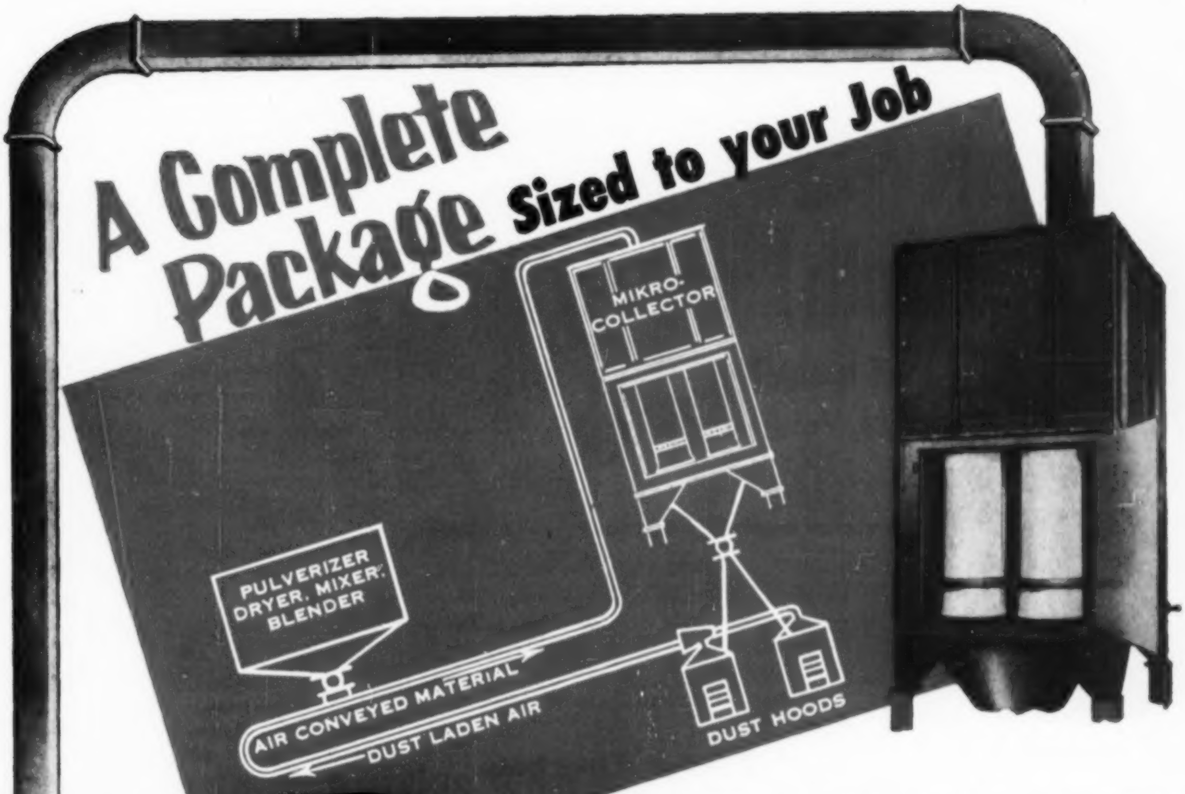
N. B. Hjersted, Mrs. Hjersted, Mrs. R. J. Cameron, Mr. Cameron, C. W. Barkow; Mrs. R. M. Berry, Mrs. Goldberg, Mr. Goldberg, Mr. Berry; Mrs. E. W. Neben; Mrs. Schramm, Mr. Schramm, Mrs. V. E. Shaw.

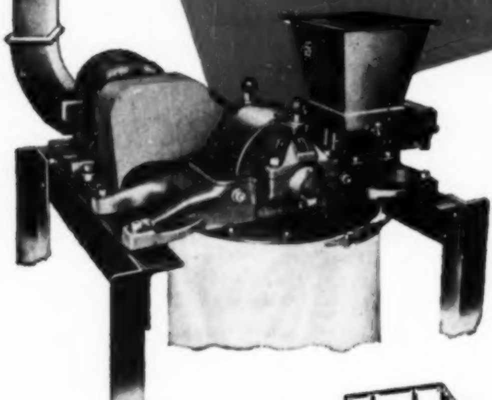
K. B. Mathur; R. M. Berry, J. E. Meyer, L. Roth and A. Kurtz trying out chuck wagon; L. Roth & Pres. C. G. Kirkbride; J. E. Meyer; Mr. & Mrs. G. O. G. Lof.

Mrs. M. W. Putnam, W. W. Wolf; general scene around "pump," chuck wagon dinner; Mr. & Mrs. E. J. Lyons; Pres. C. G. Kirkbride, E. B. Christianson, F. J. Van Antwerpen.

J. M. Noy, F. R. Minger, W. W. Wolf, C. Long; Mr. & Mrs. A. R. Van Kleeck; J. H. Rushton, J. C. Dart, unidentified; Mr. & Mrs. E. W. Neben.

NEXT MONTH—Best pictures of photo contest





Precise Grinding — Smooth Blending — Clean, Cool Air Conveying — Optimum Dust Collection All Unified In a Single MIKRO System

This One-Package MIKRO method of engineering welds three separate functions into a coordinated and completely automatic processing system which eliminates the cost of manual handling. It guarantees the delivery of a product to meet your most exacting specifications without any loss of material in process.

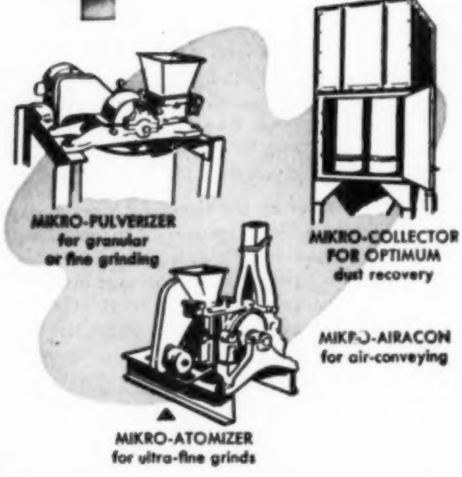
The basic grinding unit . . . either a MIKRO-PULVERIZER or a MIKRO-ATOMIZER . . . blends and grinds with ease, safety and economy and offers you a wide range of particle sizing from granular to ultra-fines.

The ground material is whisked away by the MIKRO-Airacon from any given source to any point of discharge.

In the MIKRO-COLLECTOR, where the material is filtered the reverse-jet air ring operation provides the maximum in product recovery. Here you have granular and fine powder collection at its best.

This complete MIKRO "package" thus affords you an answer to many processing and materials handling problems. The service and facilities of the MIKRO Laboratory are at your disposal, without obligation, to help obtain the best answer for you.

Write for illustrated descriptive literature.



MIKRO

PULVERIZING MACHINERY DIVISION

METALS DISINTEGRATING COMPANY, INC.

31 CHATHAM ROAD — SUMMIT, NEW JERSEY

National Meeting Report

(Continued from page 38)

shoestring ties and 'gallun hats. Soon after the first arrivals began donning their special attire, a colorful and relaxing picture began to form, with the most salty New Englander becoming indistinguishable from the true sons of the west. Advance reservations of garments soon dispensed, twice the hotel station wagon was dispatched to Denver to fill the demands of those not bringing their own outfits. The A.I.Ch.E., often first with truly colorful activities at its meetings, appears to have scored again. . . .

Hittin' the Trail. Roaring Forks Ranch wrangler Hill appraised the first group of turn-outs with the cynical eye of a man long in a profession. Two hours later, the wrangler had something to confess about chemical engineers on horseback. They weren't so bad, even for beginners. Unforgettable experience: Moonlight ride along narrow, winding mountain ledge trails to the top of Glenwood Canyon singing softly . . .

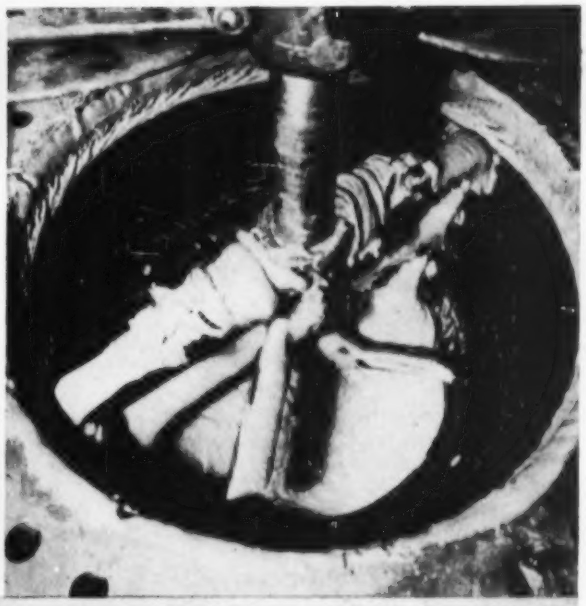
Altitude Syndrome. The pool surface glistened and shimmered in the center of the patio. In the cool of the evening, a smoky vapor arose, reminding every chemical engineer stretched out in meditative position along its sides of the thermal differences between the water and its adjacent gaseous medium. A most enticing form of relaxation . . . at least ordinarily, this pool proved surprisingly strenuous to those not acclimated to its elevation—5,800 feet. Chemical engineers tending closely to "pool duty" (see picture section) found a minimum of three days required to dissipate the hard breathing symptom. Economists discussed avidly the pay-out of such a heated swimming pool, but reached no conclusions due to lack of cost data on hot spring water supplying the B.t.u.'s.

Chuck Wagon. The overwhelming impression made by the chuck wagon dinner on the patio, by the side of the swimming pool, was an abundant supply of delectable food followed by the singing of songs of days gone by.

Trout by the Handful. A good way to get to know people is to get down to "grass roots" with them. That is, if you have grass. Out in sage brush country, one reaches for trout. Or so the local public relations committee put it to the Institute officials . . . who with several others rather "innocently" accepted an invitation to "come and catch some trout" Monday afternoon following the uranium symposium. The word

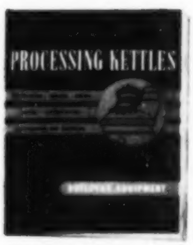
(Continued on page 74)

Heavy film on heating surface retards heat transfer, slows production —when no scraper blades are used.



Clean heating surface improves heat transfer, speeds production— when film has been completely removed by Buflovak-Dopp Scrapers.

Buflovak-Dopp Kettles with scraping agitator speed production...make a better product...save money



Write for your copy of Catalog 356-R, which contains much useful information about processing kettles.

The effectiveness of *Buflovak-Dopp* Scrapers, used in *Buflovak-Dopp* Kettles, is clearly indicated in the photographs. The results are savings up to 80% in production time on some products . . . attractive profit-building savings when processing *any* material.

Clean heating surfaces accelerate heat transfer and are therefore most important for efficient processing. For example, a stagnant film of paraffin only a hundredth of an inch thick has the same heat retarding action as a wall of cast iron 180 times thicker.

When pasty materials are being cooled, *Buflovak-Dopp* Scrapers constantly remove the stagnant material from the kettle wall . . . and move it to the center of the mass in the kettle for uniform mixing. The result is a uniform, good quality finished product.

When processing heat-sensitive materials, these continuous action scrapers protect the good quality of the product by preventing material from burning on the heating surface.

But these are only two typical examples of the effectiveness of *Buflovak-Dopp* Kettles equipped with *Buflovak-Dopp* Scrapers. To get the type of kettle and scraper that will meet your needs, the safest procedure is to process a quantity of the product and observe the results. The Pilot Plant in our Research and Testing Laboratory provides facilities for you to run such tests.

With this basic information, kettles can then be designed and built to most economically and profitably fulfill your specific processing requirements.

BUFLOVAK EQUIPMENT DIVISION
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BUFLOVAK PRODUCTS: evaporators • dryers (atmospheric and vacuum) • solvent recovery and distillation equipment • chemical plant equipment • food processing equipment • kettles • fabricated processing equipment • vulcanizers . . . plus a complete Pilot Plant for pre-testing processes and products.

Only Brown flow meters offer you these profitable "*plus*" values

- ***16 different types*** of basic instrument systems . . . a flow meter for every fluid, every pressure, every operating requirement. *You're sure to find the most profitable meter for your specific application.*

- ***Nearby service facilities.*** There's a Honeywell service center as near to you as your phone. Service by factory-trained specialists is prompt, competent and economical. *You're sure to get maintenance and start-up service without delay.*

- ***27 years of experience*** in flow metering development and application work. *You're sure to get specialized engineering on your flow metering problem.*

- ***Nationwide field organization.*** Brown flow metering consultation is available from experts in more than 90 field offices, located near every major production center. *You're sure to have application engineering on hand where and when you need it.*

industrial news

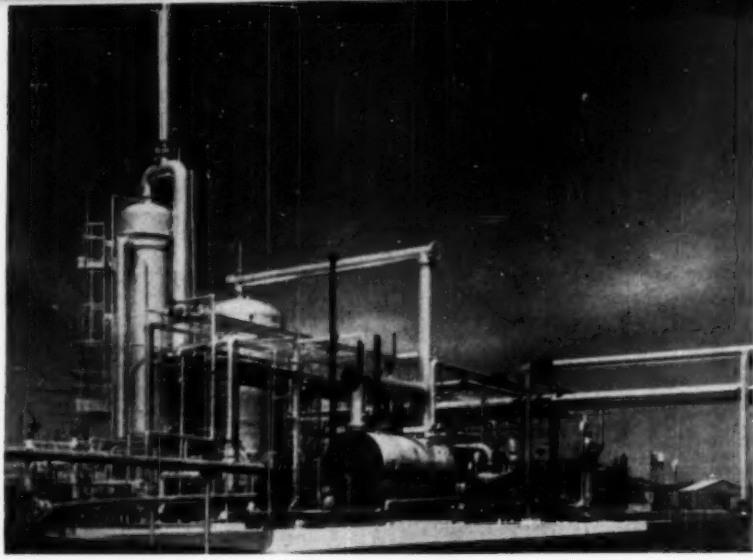
CARBIDE TITANIUM PLANT

Seventy-five hundred tons of titanium per year will be produced in a new $31,500,000 plant to be constructed for the Electro Metallurgical Company, a division of Union Carbide and Carbon Corporation, in Ashtabula, Ohio, by Catalytic Construction Company. This will be the first commercial production of titanium other than by the Kroll process. The plant, which will take about a year and a half to get into production, will produce titanium by the reduction of titanium tetrachloride with sodium.

The company has had this process in operation on a pilot and prototype plant scale at its Metals Research Laboratories in Niagara Falls, N. Y. The process has been the subject of research and development for the past five years at a cost of almost $2 million.

ANHYDROUS AMMONIA FROM COAL CHEMICALS

An anhydrous ammonia plant that will draw its raw materials exclusively from coal chemicals has been announced by Hercules Powder Co. and Alabama By-Products Corp. To be erected near Birmingham, Ala., the new plant will be designed for initial production of 45,000 tons/year. Operation is scheduled to begin in 1955.



SULFUR RECOVERY UNIT

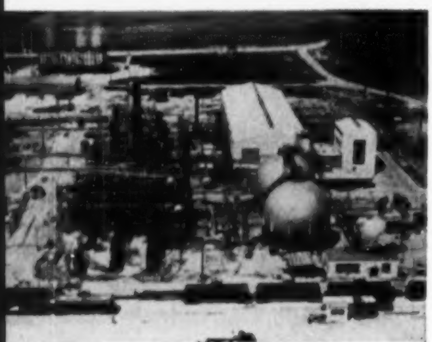
The recovery of sulfur from H_2S obtained from a sour fuel gas stream is being carried on at the new 40 ton/day sulfur recovery plant of Lago Oil and Transport Co. at their Aruba, Netherland West Indies refinery. Removal of a diethanolamine solution is employed in the removal of hydrogen sulfide from the fuel gas stream. The plant which is designed to employ sea water for cooling purposes was designed and engineered by the Girdler Co. and was constructed by the M. W. Kellogg Co.

"ELECTRONIC BRAIN" SOLVES GULF'S PROBLEMS

"An "electronic brain" to evaluate and expedite laboratory interpretation of oil refining, production and prospecting data has been added to the facilities of the Gulf Oil Corp. Laboratories in Harmaville, Pa. The computer, valued at $110,000, will be used in the rapid fire solution of increasingly numerous and difficult mathematical problems arising in every phase of petroleum research.

The benefits derived from the possession of this unit are expected to cover its original expense. It will relieve highly trained scientists from hours of laborious calculations and increase problem solution time from 50 to several hundred times the present rate. Problems previously too costly in man hours to pursue can be economically achieved.

An increase in efficiency throughout the entire structure of the organization is expected with the aid of this electronic tool. The acceleration of yield figures on experiments on refinery refinery techniques so influential in running the companies refineries may be reduced from hours to minutes. Solution of engineering problems such as are involved in the design of a distillation tower, previously uneconomical to study are made practical with the computer.



AMMONIA FOR FERTILIZER

Modifications in the process as well as the addition of more reformer furnaces is being carried on to increase the ammonia production capacity of the Mississippi Chemical Corporation's plant in Yazoo City, Miss., from 120 tons to a total of 290 tons/day. All of the increased output of the plant will be diverted to uses in fertilizers in the form of anhydrous ammonia and ammonium nitrate. The design engineering and construction services for the additional gas generating and purification facilities are being performed by the Girdler Co.

Two new ideas have been incorporated into the expansion program along with the addition of the two multi-tube reformer furnaces. Air reforming is being employed in the furnace to introduce the necessary nitrogen into the system instead of the flue gases or nitric acid tail gases used in the original plant. The substitution of a stage requiring 1,000 atmospheres of pressure prior to methanation and ammonia synthesis with a 10 lb./sq.in. gauge methanation step and modification of the methanator vessel to an ammonia synthesis converter has resulted in additional capacity with a minimum of capital expenditure. A recently developed Girdler G-29 steam-hydrocarbon reforming catalyst is being used to charge the furnace.

In the original synthesis plant the ammonia was produced by catalytic steam reforming of natural gas, followed by a single stage carbon monoxide conversion and removal by monoethanolamine.

The gas was then compressed to 1,000 atmospheres prior to high pressure methanation and ammonia synthesis. In the new scheme a second stage of carbon monoxide conversion and carbon dioxide removal is followed by the low pressure methanation step. The original high pressure methanation step is eliminated and the methanator vessel modified to an ammonia synthesis converter.

New York Meeting Preview

(*Continued from page* 36)

Simultaneously, a *general session* will include three papers exploring interesting properties of materials of construction: hydrogen vs. metals; steel undergoing contact with CO and CO_2 being hydrogenated catalytically; and a porous solid vs. changes in its drying environment. Papers like these advance the skill of the chemical engineer, whether he works in design, plant operation or equipment sales. Better try to take some of these in, for sure.

With the end of a most satisfying day drawing to a close, you might very well presume that the arrangements committee would wish you off to an evening of quiet meditation. But no, that's not what you will have come to New York to do. You, like over a thousand other chemical engineers, will be ready for their outstanding professional event of the year—

The annual awards banquet—addressed by the Secretary of Commerce

Here the high court of chemical engineering, with you as a valued guest, will sit in session to hear the announcements and descriptions of achievements by those of your fellows who have made outstanding contributions during the year. Four awards given by the Institute will be presented: the Walker Award, Professional Progress Award, Junior Member Award, and the A. McLaren White Award for the winner of the student contest program. The honored guest and principal speaker of the evening will be the Hon. Sinclair Weeks, Secretary of Commerce of the United States.

Dancing shoes

Don't forget them. For after the banquest, there will be a gala dance in the great ballroom of the Statler, with appropriate entertainment to give you a real feeling of being in the "world's entertainment center."

Wednesday—technical papers throughout the day

It will be a full day, so don't plan on leaving New York until Wednesday evening at the earliest. Starting out in the morning there will be three simultaneous technical sessions. One of these will deal with *fluids and moving beds,* largely devoted to actual process experience using these in full scale operations in sulfur recovery, petroleum refining and ammonium sulfate decomposition. Another of the papers gets specific as to the design of process systems utilizing moving beds.

(*Continued on page* 50)

New York Meeting Preview

(Continued from page 48)

It's timely to have another *reaction kinetics symposium,* another of those taking place Wednesday morning. What a heyday this one will be for process designers and developers, working in petrochemicals and a host of other industries!

The other simultaneous session, on *general papers,* will tend to concentrate on reports of investigations which enlarge our knowledge of physical properties, and means for predicting them.

Lever House—one of world's most modern skyscrapers—to be toured as part of program.

Wednesday noon—you're free again

Gang up as you will, and go as high-brow or as lowbrow as you wish as far as eateries are concerned. Just get back to the Statler by two o'clock, when another triple-header will be getting under way. One of these symposia will be on *biochemical engineering*—reporting on the progress the chemical engineer has made in the pharmaceutical industry in making antibiotics and other operations such as defatting tissues.

Second simultaneous meeting will be a continuation of the symposium on *reaction kinetics,* going into the area of fluidized and fixed beds.

Third will be a session of *general papers* carrying the chemical engineer further into his understanding of phenomena such as mixing, adsorption and absorption.

Something for everybody in this program of papers? You bet your life! No, don't bother to do that—just come to New York and take part.

(More next month)

New York Technical Program

(*Continued from page 36*)

FLUOSOLIDS PROVIDES ECONOMICAL RECOVERY OF SULFUR FROM LOW GRADE ORES, R. B. Thompson and Donald MacAskill, The Dorr Company, Stamford, Connecticut.

FLUID CHAR ADSORPTION (FCA) PROCESS, L. D. Etherington, Standard Oil Development Company, Linden, New Jersey; R. J. Fritz, E. W. Nicholson, Esso Standard Oil Company, Baton Rouge, Louisiana, and Harold W. Scheeline, Standard Oil Development Company, Linden, New Jersey.

THE FLUID HYDROFORMING PROCESS, J. C. Richards, The M. W. Kellogg Company, New York, New York.

MOVING BED PILOT PLANT FOR THE DECOMPOSITION OF AMMONIUM SULFATE, J. W. Delaplaine, Catalytic Construction Company, Philadelphia, Pennsylvania; and Robert McCullough, International Minerals and Chemical Corporation, Mulberry, Florida.

DESIGN OF PROCESS SYSTEMS UTILIZING MOVING BEDS, Clyde Berg, Union Oil Company of California, Wilmington, California.

TECHNICAL SESSION No. 8

REACTION KINETICS SYMPOSIUM, H. F. Johnstone, Presiding.

A METHOD OF CORRELATING KINETIC DATA IN HOMOGENEOUS AND HETEROGENEOUS REACTORS—APPLICATION TO TERTIARY BUTANOL DEHYDRATION, J. H. Black, J. H. Wright, J. Coull, University of Pittsburgh, Pittsburgh, Pennsylvania.

MASS TRANSFER IN PACKED BEDS, R. W. Fahien, J. M. Smith, Purdue University, Lafayette, Indiana.

EQIVALENT ISOTHERMAL TEMPERATURES FOR NON-ISOTHERMAL REACTORS, J. B. Malloy, H. S. Seelig, Standard Oil Company (Indiana), Whiting, Indiana.

KINETICS OF THE METHANE-STEAM REACTION, W. W. Akers, D. P. Camp, Rice Institute, Houston, Texas.

KINETICS OF THE CATALYZED AND UNCATALYZED LIQUID PHASE HYDRATION OF PROPYLENE OXIDE, A. L. Benham, Fred Kurata, University of Kansas, Lawrence, Kansas.

(Continued as Session 11)

TECHNICAL SESSION No. 9

GENERAL PAPERS, Roy A. Kinckiner, Presiding.

PREDICTION OF THE COMPRESSIBILITY OF GASES AND GASEOUUS MIXTURES FROM CRITICAL TEMPERATURES AND CRITICAL PRESSURES, Gouq-Jen Su, Ramesh G. Soparkar, Robert J. Lockhart, Theodore F. Morey, University of Rochester, Rochester, New York.

CORRELATION OF DIFFUSION COEFFICIENTS IN DILUTE SOLUTIONS, Pin Chang, and C. R. Wilke, University of California, Berkeley, California.

STUDIES OF THERMAL CONDUCTIVITY OF LIQUIDS, Byron C. Sakiadis, Jesse Coates, Louisiana State University, Baton Rouge, Louisiana.

VAPORIZATION RATES AND DRAG COEFFICIENTS FOR ISOOCTANE SPRAYS IN TURBULENT AIR STREAMS, Robert D. Ingebo, NACA Lewis Flight Propulsion Laboratory, Cleveland, Ohio.

TECHNICAL SESSION No. 10

(Simultaneous with Sessions No. 11 and No. 12)

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New York Technical Program

Continued from page 52

BIOCHEMICAL ENGINEERING SYMPOSIUM, C. W. Weil, Presiding.

COMMERCIAL EXTRACTION OF UNFILTERED ANTIBIOTIC FERMENTATION BROTHS IN PODBIELNIAK CENTRIFUGAL CONTACTORS, D. W. Anderson and M. F. Lau, Parke, Davis & Co., Detroit, Mich.

AN AZEOTROPIC PROCESS FOR DEHYDRATING AND DEFATTING TISSUES AT LOW TEMPERATURE, Ezra Levin and R. K. Finn, University of Illinois, Urbana, Ill.

AN APPLICATION OF ION EXCHANGE METHODS TO THE PURIFICATION OF STREPTOMYCIN, J. J. Murtaugh and I. Caldas, Jr., Schenley Laboratories, Inc., Lawrenceburg, Ind.

MIXING CHARACTERISTICS OF A MYCELIAL BROTH, G. A. Brown and Demetre N. Petsiavas, Merck & Co., Inc., Rahway, N. J.

AUTOMATIC TRANSLATION OF AERATION DATA BETWEEN DIFFERENT FERMENTORS, Ping Shu, Pairie Regional Laboratory, National Research Council of Canada, Saskatoon, Saskatchewan.

TECHNICAL SESSION No. 11

(Simultaneous with Sessions No. 10 and No. 12)

REACTION KINETICS SYMPOSIUM, Arthur J. Madden, Presiding.

THE EFFECT OF FLUIDIZATION ON CATALYTIC REACTIONS IN GAS-SOLID SYSTEMS, J. F. Mathis and C. C. Watson, University of Wisconsin, Madison, Wis.

LOW TEMPERATURE OXIDATION OF AMMONIA IN FIXED AND FLUIDIZED BEDS, H. F. Johnstone, J. D. Batchelor, and C. Y. Shen, University of Illinois, Urbana, Ill.

TURBULENT DIFFUSION IN PARTICULATE FLUIDIZED BED, T. Hanratty, G. Latinen and R. H. Wilhelm, Princeton University, Princeton, N. J.

REGENERATION OF FLUIDIZED CRACKING CATALYSTS, W. F. Pansing, Standard Oil Co. (Indiana), Whiting, Ind.

HEAT AND MASS TRANSFER IN PACKED BEDS, D. A. Plautz and H. F. Johnstone, University of Illinois, Urbana, Ill.

TECHNICAL SESSION No. 12

(Simultaneous with Sessions No. 10 and No. 11)

GENERAL PAPERS, Charles F. Bonilla, Presiding.

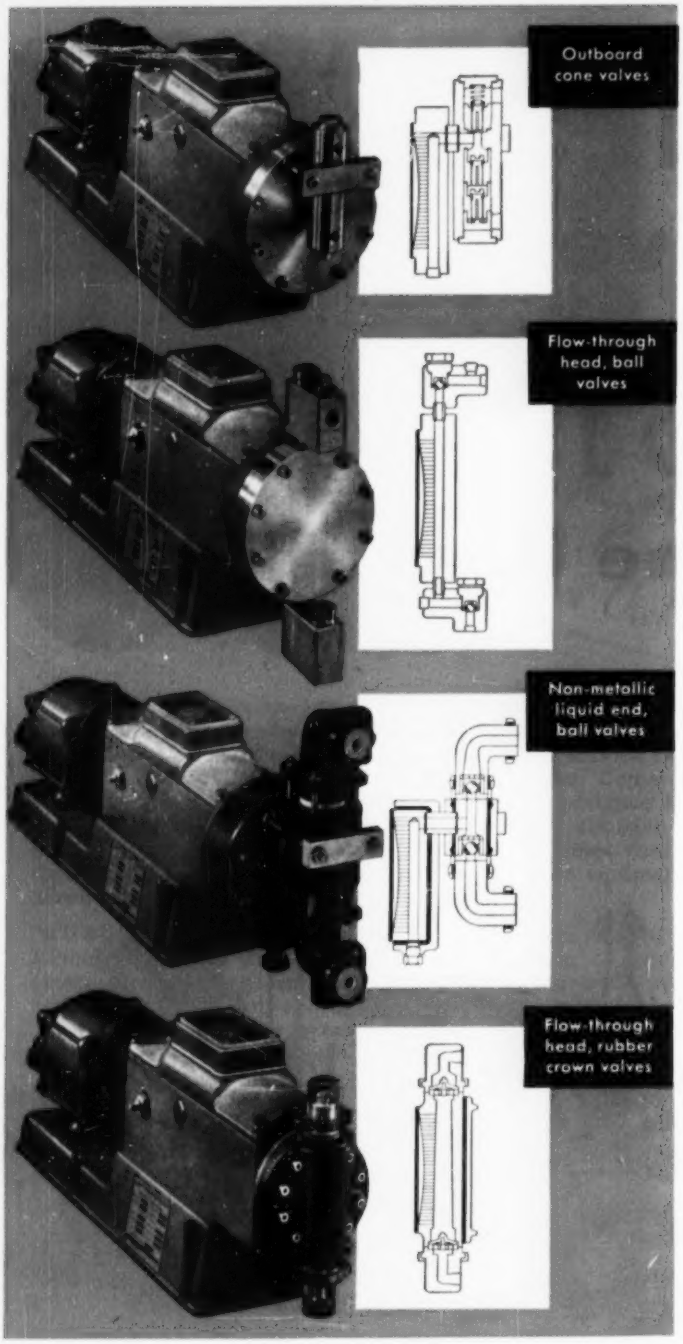
ANALYSIS OF GAS-FLUIDIZED SOLID SYSTEMS BY X-RAY ABSORPTION, E. W. Grohse, General Electric Co., Schenectady, N. Y.

FRACTIONATION OF GAS MIXTURES IN A MOVING BED ADSORBER, J. Happel, C. J. Marsel, W. H. Kapfer, New York University, New York, N. Y., and M. Malow, Scientific Design Co., New York, N. Y.

ADSORPTION PHASE EQUILIBRIUM CORRELATIONS, L. D. Etherington, R. E. D. Haney, W. A. Herbst, and H. W. Scheeline, Stnadard Oil Development Co., Linden, N. J.

GAS-LIQUID CONTACTING WITH MULTIPLE MIXING TURBINES, J. H. Rushton, and J. B. Gallagher, Illinois Institute of Technology, Chicago, Ill., and J. Y. Oldshue, Mixing Equipment Co., Rochester, N. Y.

PERFORMANCE OF PACKED COLUMNS, III HOLDUPS FOR AQUEOUS AND NONAQUEOUS SYSTEMS, H. L. Shulman, C. F. Ullrich, N. Wells, and A. Z. Proulx, Clarkson College of Technology, Potsdam, N. Y.



4 VALVE CONSTRUCTIONS

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PISTON-DIAPHRAGM CONTROLLED-VOLUME CHEMICAL PUMPS

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a chemical engineer goes to the instrument show show

What would a chemical engineer have seen and noted at the Instrument Show? C.E.P.'s editors visited with cameras and notebooks. Further information can be had from the manufacturers through using the convenient lower post card in Data Service Section, opposite page 62.

Typical interest on part of visitors is shown in this candid shot taken from behind a Milton Roy controlled volume pump exhibit.

J. B. Mellecker & R. W. Glasheen—CEP Staff

201

On right, chemical engineer J. Louis Pierce, a member of A.I.Ch.E. visiting the show from Greenville, N. C. He is discussing flow regulation with W. A. Kates, who is holding a new type "5" unit which handles up to 20 gal./min. at 300 lb./sq.in. maximum. Also shown is top of largest Kates Regulator, up to 550 gal./min. at 300 lb./sq.in. max.

202

Fischer & Porter's Automatic Data Logging Units (shown on right) Scans 2,000 thermocouples, prints readings at rate of 3/sec. Has completely mechanical conversion from analog to digital readings. Tape punched by machine, then fed into IBM computer, or punched tape can be fed into machine to program operation of control units.

203

Bristol's Metagraphic recorder chassis shown removed from case set in graphic panel board. End connections near finger are pneumatic; special pointer on face warns if these are not tightly sealed. Easily and quickly removed from mounting by opening door and sliding chassis on rails.

204

Part of Minneapolis-Honeywell exhibit demonstrating variety of sensing elements which can be connected to their electronic recorder. Less than one-fifth of the total display of sensing units are shown by the photograph.

205

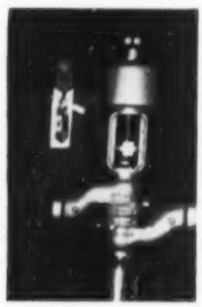
Flashing-flow plug for 4-in. Hammel-Dahl double seated flow-regulating control valve. Perforations reduce vibration and pounding experienced with solid plugs when used with liquid having flashing tendency when passing through venturi-type constrictions of valve chamber.

206

Hammel-Dahl flow-regulating control valve for high-pressure service . . . to 3,600 lb./sq.in. Constructed in manner to assure tight seal when closed.

207

Continuous process monitoring mass spectrometer by Consolidated Engineering Corp. Model 21-610 is designed to continuously measure and control the amount of various constituents in a liquid or gaseous process stream. Resolves between beams of one mass unit differential up to a mass of 40.

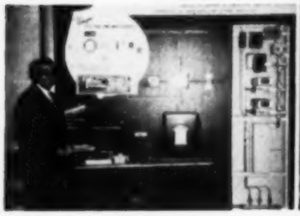


208

Largest Annin single seated modulating control valve made. 8-in. size, rated at 1440 lb./sq.in. at 100° F. Features simplicity of construction, standardized parts. Driven by air motor developing 4,000 lb./sq.in. thrust with stroke speed of 1-in./sec. over 6-in. stroke. Kanigen coated. (D. H. Annin)

(*Continued on page 59*)

a chemical engineer goes to the instrument show — *(Continued from page 57)*



209

Foxboro EMF Pneumatic Transmitter. Device converts dc measurement input signal into proportional pneumatic output signal of 3-15 lb./sq.in. Designed to couple electrical output signals from sensing elements, to pneumatic controllers. In photo, assembled unit is at bottom of circular area. Panel at right shows typical mounting arrangement. On table is chassis. (R. Silva)

210

Safety bursting disc display by Black, Sivalls & Bryson. Model demonstrated is new "D" or "DV" disc applicable to systems operating in range 4-15 lb./sq.in. An assembly of elements, all are rigidly fixed until unit is within close range of rating. Vacuum or pressure. 1¼ to 24 in. sizes. Corrosion-resisting alloys. (J. F. Myers)

211

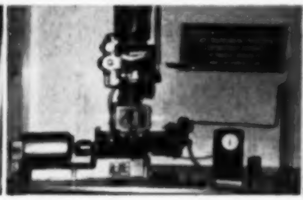
Bristol's Metagraphic absolute pressure transmitter which functions entirely independent of fluctuations in atmospheric pressure. Especially useful in vacuum processing. Range, 0 to 5 mm. mercury, absolute.

212

Gyro Mass Meter by Control Engineering Corporation. Rotating bourdon tubes, through which liquid is passed, continuously monitor mass, transmit linear motion along axis to differential transformer which produces electrical signal. Said to be particularly useful in blending operations.

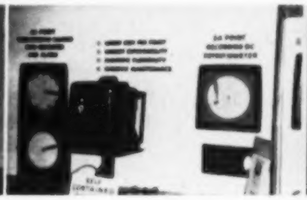
213

DeZurik plug valve assembly, equipped with positioning type pneumatic operator with remote manual control, providing throttling action. DeZurik plug valve employs a special type of plug which turns out of the flowstream, making the valve useful for fibrous, granular slurries and viscous liquids. Rated to 200 lb./sq.in., available in alloys.



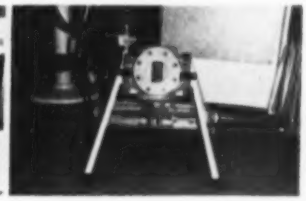
214

Lapp positive displacement piston, hydraulically-balanced diaphragm proportioning pump. Has auto-pneumatic stroke-length adjustment which responds to 3-15 lb./sq.in. instrument air pressure signal. Has no packing gland or running seals. Flow range adjustable from 0-3 ranging to 0-12 gal./hr.



215

Center—Fielden scanning system by Robertshaw-Fulton. Neon lights on face remain lit throughout scanning cycles of either 10 thermocouple points/sec. or 1 point/sec. Light going out indicates thermocouple is off set point. **Left**—Rotating hand scanning indicator. Hand stops and indicates element off set point. **Right**—24-point recorder using 6-colors on 4-segments of chart.

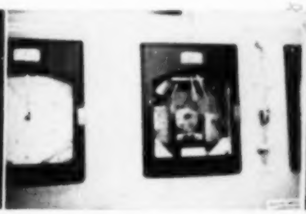


216

A.C.F. Industries three-way proportioning cylindrical plug valve connected to Ledeen pneumatic operator. Valve is lubricated type, and when open presents round, full pipe area port opening.

217

Pressure control pilot by Black, Sivalls & Bryson. Used to control air-actuated diaphragm regulating valves. Pneumatic signal from sensing element may be vacuum or pressure. Bourdon tube in unit responds, actuating diaphragm power unit relay. Throttling range adjustable 0-100%. Easily adjusted. (J. Dvoracek)

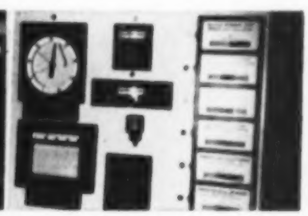


218

Display showing Fischer & Porter recorder with dual controllers of stack type, with motion-balance input.

219

Minneapolis-Honeywell display panel indicating the variety of inter-related sensing elements, indicating and recording instruments, and power units.



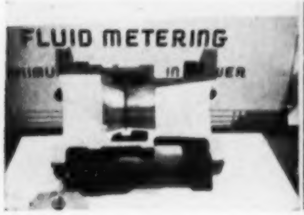
220

Minneapolis-Honeywell's line of electric temperature controllers.

for further information, use post card in Data Service Section, opposite page 62

(Continued on page 60)

a chemical engineer goes to the instrument show — *(Continued from page 59)*



221

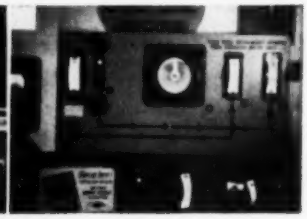
Builders-Providence "Dall" flow tube is used in metering liquid flow. Features high pressure recovery, representing a major improvement over the venturi tube, according to manufacturer. Where maximum recovery of head loss is desired, the Dall unit may be especially designed for this purpose.

222

U. S. Electrical Motors variable speed/drive/control unit, called "Varitrol." In one of the applications demonstrated, tape was being transferred from one reel to another at constant linear speed. Motor used is "Varidrive," variable speed motor.

223

Inflated-gasket sealed butterfly valve by Continental Equipment Co. Designed for positive seal under high pressure differentials. Neoprene or silicone rubber seal is clamped between halves of valve body. Shaft enters at an angle to avoid piercing of gasket. After closing, pressure from upstream line is applied to gasket causing tight seating. (M. H. Prestia)



224

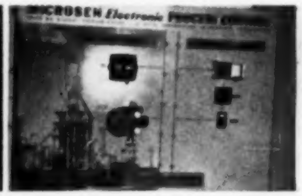
Yarnall-Waring liquid level indicator measures contents of tanks under pressure as high as 2,500 lb./sq.in. Indicates directly, or remotely through an electronic relay to receiving points up to one mile distant. No bearings under pressure. Range, 8-in. water minimum, 22-ft. maximum.

225

Panalog scanning, monitoring data processing and reduction system. Electric typewriter in foreground printing data.

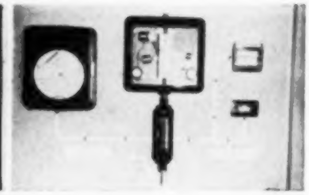
226

Milton Roy high pressure, large capacity controlled volume pump, for pressures up to 50,000 lb./sq.in.



227

Manning, Maxwell & Moore display of Microsen system for remote electronic-pneumatic process control. Upper left—electronic pressure transmitter in explosion-proof housing which sends out a d.c. signal to the control area (on right). This returns another d.c. signal to electro-pneumatic valve positioner (lower right), also explosion-proof.



228

Leeds & Northrup panel-mounted pH indicator, which represents an industrial version of the line operated pH indicator to demonstrate its stability and performance in an industrial process.

229

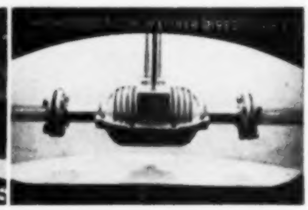
Fischer & Porter miniature recorder being removed from its housing on a flow-panel board. This view shows its pneumatic and electrical connections which remain intact with the instrument in the withdrawn position shown.

230

Left—A.C.F. Industries 3-way, 3-port cylindrical plug, round port valve. **Right** — Straight-through round port valve. Available in various alloys, bronze and semi-steel. Port area and shape same as pipe.

231

Continuous infra-red plant stream analyzer by Liston-Becker. Model 21 is rated with pressure limit of 1,500 lb./sq.in. Sensing unit being point to, enclosed in standard Crouse-Hinds explosion-proof housing. At rear is amplifier and recorder. Operates on positive principal, pneumatic detector. Uses standard gas for periodic calibration, remotely controlled.



232

Foxboro electromagnetic flowmeter has no internal obstructions, for use with any liquid, slurry or sludge with conductivity greater than 200 micromhos Operates on induction principle, with liquid in motion cutting lines of magnetic force, producing measurable emf between immersed electrodes. Sizes 2- to 8-in. available standard, larger on order.

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(End)

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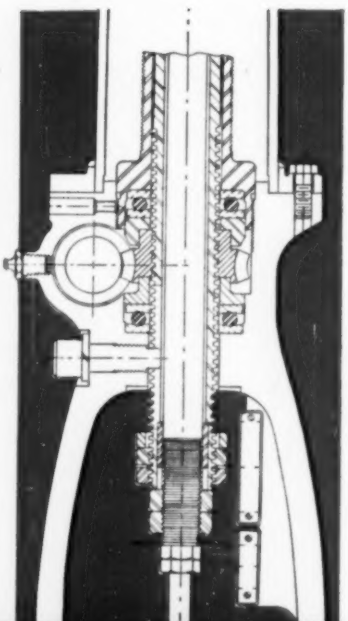

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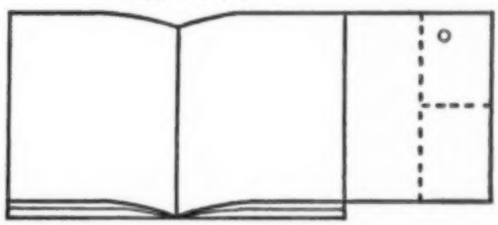

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24L **Alkyd Resin Installations.** Designed for Dowtherm, electricity, gas or oil heat, constructed in all types of stainless steel. Industrial Process Engineers

25A **Electric Motors.** New booklet illustrates three principal types of bearing systems used in motors. Edited by lubrication engineers. U. S. Electrical Motors Inc.

26A **Diatomite Powders.** Absorb twice their own weight of liquid. For fluffing up household cleansers and pigments in paint and paper. Johns-Manville

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32A **Proportioning Pump.** For additives or chemical reagents. Built-in standard motor—no separate gearbox or couplings. Proportioneers, Inc., Div. of B-I-F Industries, Inc.

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35A **Gasholders.** Dry fabric seal eliminates maintenance problems. Wiggins Gasholder Div., General American Transportation Corp.

37A **Automatic Process Controls.** Engineering, design and manufacture. Black, Sivalls & Bryson, Inc., Climax Controls Div.

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42L **Pumps, Valves, Pipes and Fittings.** Centrifugal pumps; globe, angle and Y valves; pipe and fittings. Vanton Pump & Equipment Corp.

43A **Buflovak-Dopp Kettles.** Scrapers constantly remove stagnant material from the kettle wall, move it to the center for uniform mixing. Buflovak Equipment Div., Blaw-Knox Co.

44A **Brown Flow Meters.** 16 different types of basic instrument systems. A flow meter for every fluid. Minneapolis-Honeywell Regulator Co.

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48L **Acid-Proof Metal.** Tantalum, for most acid solutions and corrosive gases or vapors except HF, alkalis, or substances containing free SO_3. Fansteel Metallurgical Corp.

Chemical Engineering Progress

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Be sure to give name, address, position, etc.

Remember, the numbers on the upper portion of the card bring you data on only the bulletins, equipment, services, and chemicals reported in these information insert pages. The lower portion of the card is for the advertised products, and is keyed not only to advertising pages, but also to the memory-tickling list under the heading Products.

49A **Research and Development Center.** For industries concerned with liquid-solids separation through vacuum or pressure filtration. Engineering and research personnel. The Eimco Corp.

50L **Antifoam A.** Odorless and tasteless silicone defoamer. Physiologically harmless in food at concentrations up to 10 p.p.m. Also Antifoam AF, a dilutable defoamer containing 30% Antifoam A. Dow Corning Corp.

50R **Crucibles, Dishes, Trays.** Noncatalytic. Nonporous. Vitreosil does not absorb material. The Thermal Syndicate, Ltd.

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52L **Heat Exchangers.** Pressure: 300 lb./sq.in. gauge; temperature: 1,200° F.; capacities: 750,000 to 8,000,000 B.t.u./hr. Other types. Thermal Research & Engineering Corp.

53A **Stainless Steel Products.** Castings, jet aircraft engine rings, valves, fittings and accessories. Cooper Alloy Corp.

54L **"Rubberhide" Linings.** Compounded from rubber or neoprene to provide resistance to specific corrosive agents. Goodall Rubber Co.

55A **Houdriforming.** Catalytic reforming process for higher octane motor fuels. Also for high yields of benzene, toluene, and xylenes. Houdry Process Corp.

56A **Controlled-Volume Pumps.** Piston-diaphragm pump for controlled-volume pumping. Lapp Insulator Co., Inc.

(Continued on back of this insert)

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100L	100TR	100BR	101B	IBC	OBC			

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about instrument show described

on pages 57, 59 and 60

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Company ....

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October, 1954

PRODUCTS *(Continued)*

58A **Heat Transfer Medium.** High temperatures with low pressures made possible by this heat transfer medium. The Dow Chemical Co.

61A **Designing Engineers and Constructors.** Processes for the manufacture of alcohols, styrene, toluene, butadiene, ethylene, propylene, acetylene, and other chemicals. The Lummus Co.

62A **Valves.** Continuously connected handwheel achieved by integrating parts in the completely enclosed gear housing. Hammel-Dahl Co.

67A **Blending.** 5 cu.ft. stainless steel blender, equipped with intensifier bar, blends four basic vitamins. The Patterson-Kelley Co., Inc.

71A **Pressure Leaf Filters.** Manufacturer stresses service program. Vertical and horizontal filters. Niagara Filters Div., American Machine and Metals, Inc.

72L **Fullers Earth.** Used in the adsorptive refining, decolorization, clarification and neutralization of mineral, vegetable, and animal oils, fats and waxes. Floridin Co.

73A **Glass Pipe.** Manufacturer states "pipe would last 203 years on a diet of hot hydrochloric acid." Corning Glass Works

74L **Chlorination.** Slime control equipment designed for any need. Wallace & Tiernan

75T **Automatic Control Valves.** Straight-through flow, sizes from ½ in. through 20 in. All castable metals. DeZurik Shower Co.

75B **Ejectors.** Steam jet air ejectors designed to meet conditions of individual installations. Condenser Service & Engineering Co., Inc.

76L **Feeders.** Positive constant-weight feed rate regardless of feed size or volumetric variation. Also grinding mill, and feed controls. Hardinge Co., Inc.

76R **Book.** "The Technology of Solvents and Plasticizers" by Arthur K. Doolittle. John Wiley & Sons, Inc.

77R **Heat Exchangers.** For heating, cooling, process, and air conditioning. Aerofin Corp.

78L **Heat Exchangers.** Also centrifugal pumps, rupture disks, absorbers, towers, etc. Falls Industries, Inc.

79R **Air Conditioning Method.** Dries air directly and measurably, using a moisture-absorbing liquid spray. Niagara Blower Co.

80L **Valves.** Dry valves, self-cleaning, free flowing, straight-through clear passage. Sizes from 3 to 24 in. General Machine Co. of New Jersey

80R **Heat Exchangers.** Solvent recovery equipment, extraction coils, evaporators, reaction vessels, etc. Davis Engineering Corp.

81R **Flexible Joints.** For refinery towers, stacks, large piping. Size 1 in.—6,000 lb., 1½ in.—8,000 lb., 2 in.—12,000 lb., 3 in.—20,000 lb. Barco Manufacturing Co.

82L **Tank Heaters.** Manufacturer states finned construction provides "approximately 7 times more heating surface per foot of tube length than plain bare pipe or tubing." Brown Fintube Co.

83R **Wire Cloth.** Made of all malleable metals. Meshes, ranging from 4 in. space cloth, up to 400 mesh. Newark Wire Cloth Co.

85R **Oxygen Analyzers.** Provide direct physical measurement of the oxygen itself. Arnold O. Beckman, Inc.

86T **Filters.** For laboratory and small lot production. Lab or batch filtration of 5 to 10 gal. Ertel Engineering Corp.

86B **Loader and Piler.** Will load and trim up to 150 tons/hr. of granular material up to 2 in. lump size. Stephens-Adamson Mfg. Co.

87R **Valves.** For 66° Bé. sulfuric acid service. Available in sizes ¼ in. through 2 in. The Duriron Co., Inc.

88L **Pumps and Compressors.** Built-in valve automatically prevents reverse flow through compressor and also dampens pipe line pulsations. Pennsylvania Pump & Compressor Co.

88R **Industrial Equipment.** Dust and fume eliminators, industrial ovens, spray booths, and mechanical washers. Schmieg Industries, Inc.

89R **Protective Coatings.** Can be applied to a heavy thickness by spraying or brushing without sacrificing acid and solvent resistance characteristics. Carboline Co.

90TL **Meters.** Will handle 856 different liquids in processing, blending, packaging and many other batching or blending operations. Bowser, Inc.

90BL **Soluble Coffee Plants.** Engineered upon the most modern developments in coffee extraction and drying. Foster D. Snell, Inc.

91R **Heat Exchangers.** Manufacturer offers "custom-built" quality with "two-three week delivery." Downingtown Iron Works, Inc.

92L **Ion Exchange Equipment.** For removing excess amounts of ammonia and organic amines in the synthesis of methanol from carbon dioxide and hydrogen. Illinois Water Treatment Co.

93T **Mixers.** Mixing, blending, suspending or dissolving. Portable. Sizes from 1/20 hp. to 7½ hp. Alsop Engineering Corp.

93B **Proportioning Pumps.** 7,500, 15,000 or 30,000 lb./sq.in. working pressure by the interchange of piston and cylinder assemblies. American Instrument Co., Inc.

94T **Skin Barrier Cream.** Indicated to offer skin protection against irritants and sensitizing agents encountered in industry. Ayerst Laboratories

94B **Spraco Nozzles.** Full cone, flat spray and hollow cone spray nozzles. Catalog. Spray Engineering Co.

95TL **Process Equipment.** Made of stainless steel, monel, inconel, nickel and aluminum. Alloy Fabricators Div. of Continental Copper and Steel Industries, Inc.

95BL **Filter Media.** Engineered for optimum efficiency in handling countless exposure conditions. Micro Metallic Corp.

95R **Photochemical Equipment.** Source for actinically sensitized high-pressure reactions. For production involving synthesis, decomposition, hydrolysis, hydrogenation, etc. Hanovia Chemical & Mfg. Co.

97T **Variable Speed Pulleys.** Available in 8 sizes—fractional to 10 hp. with ratios to 3 to 1. Lovejoy Flexible Coupling Co.

(Continued on page 68)

97B **Process Piping.** Any diameter up to 60 in.; wall thicknesses to ⅜ in.; temperatures to 2,200°. The Pressed Steel Co.

99R **Tank Hood.** Credited with "saving its entire cost" since "no previously used material had lasted over a year." Molded from resin-bonded glass fibre laminate. The Chemical Corp.

100L **Color Comparators.** For pH, chlorine tests. W. A. Taylor and Co.

100TR **Jaw Crushers.** For crushing ores, graphite, rare earths, ceramic wastes, synthetic mica, & phenodichlorobenzene. Stationary and mobile units. Gruendler Crusher & Pulverizer Co.

100BR **Tank Meter.** For measuring tank contents any distance away. Also hydrostatic gauges for all purposes. Uehling Instrument Co.

101B **Evactors.** Illustration shows two 4-stage evactor units in pharmaceuticals plant. Also jet mixers, jet heaters, etc. Croll-Reynolds Co., Inc.

IBC **Process Engineering.** Experience in distillation, evaporation, extraction, and absorption. The Vulcan Copper & Supply Co.

OBC **Fluid Mixers.** Tells how to choose a fluid mixer. Catalogs. Mixing Equipment Co., Inc.

BULLETINS

1 **Heat Exchangers.** For process applications, tubular exchangers equipment from Colonial Iron Works. Literature illustrates & describes standard exchangers employing IPS shells. Modification of basic tube sheet templates permits pre-design & fabrication of standard units in 1, 2, 4, 6, 8-pass arrangements in various types. For any tube length., with pressure ratings 15 lb./sq.in. gauge; also 75, 150 & 200 lb./sq.in. gauge. Section on new self-supporting evaporators.

2 **Lattice Braid Packing.** New folder describes Garlock Packing Co. lattice braid packing for all services. Features longer life, fewer repackings, faster sealing, fewer gland adjustments. Types, dimensions, general recommendations included.

3 **Flow Rate Test Kit.** Lo-flow Rota-Kit a compact self-contained portable test kit for measuring liquids & gases. Four ranges provide .1 cc./min. to 1,400 cc./min. flow rate of water or equivalent. Folder includes gas flow chart, operating principle, illustrations. Ace Glass Inc.

4 **Flexible Ball Joints.** Binder insert bulletin from Barco Mfg. Co. on flexible, swivel, swing & revolving joints. Includes service information, standard styles & sizes, pressure rating charts, dimensions.

5 **Process Equipment.** Ovens, dryers, conditioners for industrial uses illustrated in folder from Lyden Bros., Inc.

6 **Valves.** Loose leaf binder catalog from Marotta Valve Corp. on valves extensively used for pneumatic or hydraulic control in petroleum & other chemical process industries. Flow curves, cutaway views, specifications on each type.

7 **Plug Valve Actuators.** Bulletin from Ledeen Mfg. Co. describes tandem type actuators for valves requiring high torques to operate. Floating bar type for lower operating torques. Selection table, applications, mountings, dimensions, weights, diagrams included.

8 **Vacuum Pumps.** Dry vacuum pumps both slide valve & rotary oil sealed types illustrated & discussed in brochure from J. P. Devine Mfg. Co., Inc. Schematic drawings, construction, specifications, tables given.

9 **Filter Cloth.** A polyethylene filter cloth said to provide excellent chemical resistance in a monofilament fabric inherently free flowing, easily cleaned. Shrinkage minimized to 212° F. Resists attack from most acids, common alkalis, & mildew. Moisture absorption factor less than 0.01%. National Filter Media Corp.

10 **Control Valves.** Needle type control valves by Foxboro Co. discussed & illustrated in new catalog. Tables, curves, diagrams shown. Sizes ½ to 1 in., with either parabolic or slab type needle inner valves in corrosion & erosion-resistant metals.

11 **Regulators.** High pressure & corrosion resistant Gas-O-Dome regulators for use in control of many types of gases & fluids, illustrated in catalog from Victor Equipment Co. Pressure range from 0 to 10,000 lb./sq.in. Gas volumes to 600 cu.ft./min.

12 **Separator.** Efficient use in single or multiple deck screening, Sweco Separator, Southwestern Engineering Co. Said to provide greater production capacity. From coarse to 325 mesh. Unit is self-contained, easily changed, only three moving parts.

14 **Valves.** Gate, control angle, other types of valves for use in chemical process industries included in illustrated, loose-leaf catalog from Gas Machinery Co. Schematic diagrams, tables, details on each type included.

15 **Plastice Pipe & Fittings.** Rigid P.V.C. pipe & fittings both normal & high impact unplasticized. Light weight, easily installed & fabricated. Good chemical resistance, tensile & flexural strength. Low inflammability. List of properties, schematic drawings, information on fabrication, machining, etc. given in catalog. Alpha Plastics Inc.

16 **Technical Papers.** (16) Technical paper on using controlled
17 volume pumps. (17) For control volume pumping of minute flows. Papers describe three applications. Milton Roy Co.

18 **Rubber Products.** New edition of rubber products catalog from Raybestos-Manhattan, Inc. covering V-belts, transmission & conveyor belts, hose, molded products.

19 **Refrigerant Cooler.** Doyle & Roth Mfg. Co., Inc. coolers & condensers for applications not encountered in everyday refrigerating practice.

20 **Vitrified Clay Pipe.** Folder from Robinson Clay Product Co. covers use of vitrified clay & Screw-Seal pipe for chemical drainage ducts, laboratory fume & ventilating ducts. Unaffected by corrosive action of acids, gases & commonly used chemicals.

21 **Protective Coatings.** "Positive Protection," booklet from Rowe Paint & Varnish Co., Inc describes system of custom made protective coatings for the chemical process & allied industries.

22 **Aluminum Heat Exchangers.** The "A" to "X" of aluminum heat exchangers is subject of Aluminum Company of America technical booklet. Complete story emphasizes factors providing low cost & corrosion resistance.

23 **Cast Alloy Reference Sheets.** Booklet from Cooper Alloy Foundry Co. includes series of eleven cast alloy reference sheets. Information concerning chemical composition, mechanical & physical properties, resistance to corrosive solutions on each alloy.

24 **Skip Hoists.** For handling bulk materials of all kinds, skip hoists from C. O. Bartlett & Snow Co. Bulletin lists applications & advantages, capacities.

25 **Reformer.** Details on a reforming process for production of interchangeable gases at low cost contained in bulletin on Koppers-Hasche reforming furnace from Koppers Co., Inc. Cutaway view in color, flow diagram, description of equipment.

26 **Plant Facilities.** From Hardinge Mfg. Co. folder describing plant facilities. Illustrated with photos of various large & small fabricating tools & typical products of machines, plate & pattern shops.

27 **Productive Maintenance.** General Electric Company's brochure on a 5-step productive maintenance plan suggests procedure for automation in future industry. Covers all phases of subject with text, charts, illustrations.

28 **DeMisters.** Bulletin from Otto H. York Co., Inc. on York-mesh DeMisters. Clean separation between liquid and vapor in vacuum towers, distillation equipment, evaporators, & drums. Features improved efficiency, throughput capacity, overhead quality. Several types, construction, vapor velocities listed. Also describes York-Scheibel multi-stage extraction column.

29 **End-Mounted Pumps.** Single stage, side suction, end mounted pumps for chemical service illustrated in bulletin from Roy E. Roth Co. N.P.S.H. rated for use with acids, caustics, solvents. Said to deliver high pressures at medium & low capacities. Range to 200 lb./sq.in. Viscosities to 200 centipoises. Additional data & general information.

30 **Pressure Pickup.** Photocon Research Products leaflet on a pickup capable of measurement at 6000° F. Ranges from 1 lb./sq.in. to 75,000 lb./sq.in. Insensitivity to cable vibrations & shock. Resistant to highly corrosive atmospheres.

31 **Pneumatic Roller Mills.** Catalog from Bradley Pulverizer Co. illustrates various types of screen & pneumatic roller mills for pulverizing non-metallic minerals to range of 20 to 325 mesh. Details on each type plus schematic diagrams.

32 **Gas Analysers.** Two gas analysers to meet demand for accuracy, sensitivity, reliability & ruggedness made by Charles Engelhard, Inc. Featured are continued monitoring of gas flow by indicator. Used in pulp & paper, smelting, process, ceramic industries.

33 **Gas Purifiers.** Catalytic purification, hydrogenation & oxidation of gases using Baker & Co. equipment discussed in folder.

34 **Plate Design & Fabrication.** Tippett and Wood fabricators of plate from $\frac{1}{16}$ to 3 in. thick describe facilities in folder. Prepared to form any shape desired.

35 **Tubing.** Both stainless steel, nickel & nickel alloy tubing available from J. Bishop & Co. Platinum Works. Tables of properties, other pertinent data.

36 **Centrifugal Separators.** Booklet from Centrico Inc., distributors of Westfalia products details performance of three models for purifying fuel & lube oils. Also describes new hydraulic lifter & exchangeable bowl liners which reduce cleaning downtime 60%.

EQUIPMENT

40 **Relief Valves & Strainers.** Catalog section on relief valves & strainers from Edward Valves, Inc. includes details of newly designed union bonnet strainers sizes 1¼ to 2 in.

41 **Rotary Sifter.** Larger models of all-metal Bar-Nun rotary sifters from B. F. Gump Co. announced in bulletin featuring uniform rotary motion over entire area. Equipment for feeding, continuous mixing, packing, weighing also available.

42 **Hot Extrusions.** Literature now available from Allegheny Ludlum Steel Co. on hot extrusions in stainless & tool steels, high temperature alloys & other steels, in any required shape.

43 **Recording Spectrometer.** Designed for multiplier phototube detection & measurement of spectrum including near ultraviolet & visible spectra. Used in spectrum analysis of gas discharge tubes, isotope-radio determination. Leeds & Northrup Co.

44 **Welding Material.** Strength & ease of handling claimed for Tygoweld, an organic welding material from U. S. Stoneware Co. Rod form can be applied with moderate heats & little pressure.

45 **Clad Metal.** Silver clad brass & phosphor bronze .00001 in. thick currently produced by American Silver Co., Inc. Produced in strip & to close tolerances & ultra-thin gauges.

46 **Mass Spectrometer.** Hydrocarbon waxes & other compounds in high mass ranges may now be broken down by Consolidated Engineering Corp. model 21-103C mass spectrometer. New model doubles range of complete resolution by increasing readings to mass 350. Equipped with one-piece stainless analyzer.

47 **Gas Analyzer.** Gow-Mac Instrument Co. announce panel-type instruments for plant stream. Ready to install in processing systems, equipment includes Electronik recorder, flow regulators & meters.

48 **Microballoon.** Techn al performance data on microscopic spheres made of Bakelite phenolic resin which form the new oil storage evaporation barrier is available in illustrated booklet from Bakelite Co. Describes ½ in. floating layers of the hollow spheres & how they have reduced crude oil evaporation losses by 80 to 90% in existing cone-roof storage tanks.

49 **Thermal Conduction Material.** Tracit a mortar-like material self-hardening when set, resistant to mechanical & thermal shock. Produced by Chemax Mfg. Corp. Easily applied. Bonds strongly to surface. Excellent heat transfer & high compressive strength.

50 **Analysis Die.** Perkin-Elmer Corp. announces an evacuable die for making transparent discs for infrared analyses of solids.

51 **Tank Gauge & Null-Balance Receiver.** (51) Revolutionary
52 tank gauge measures liquid depth by electronics. Designed for accuracy to $\frac{1}{16}$ in.±. For refineries, terminals & tank farms. (52) Null-balance receiver designed to eliminate mechanical vibrators. Gilbert & Barker Mfg. Co.

53 **Conveyor Belt Cleaner.** Spring-type conveyor belt cleaner using no moving parts from Stephens-Adamson Mfg. Co. is described & illustrated in folder. Removes adhering material from belt after discharge.

54 **Temperature Controllers.** Precision temperature controllers from Technical Equipment Co. Ranges −100° C to 500° C ranges with 0.001° C control accuracy over entire range.

55 **Turbo Pump.** Type DE turbo pump developed by J. S. Coffin, Jr., Co. 16 in. pitch diam. turbine operates at 8,500 rev./min. normal with sample speed for efficient extraction of available energy of the steam. **

58 Electrical-Grade Plastics. Now available from National Vulcanized Fibre Co. a paper-base electrical grade plastic bonded with polyester-modified melamine resin. Eliminates difficult machining properties presently encountered. Good dielectric strength, low dissipation factor & good moisture resistance.

59 Water Conditioner. Said to eliminate scale & corrosion without the use of chemicals is a water conditioner from Packard Mfg. Co. No moving parts, economical maintenance.

60 Geiger Counter Monitor. Nuclear Instrument & Chemical Corp. offer monitor for use with a Geiger counter for use in surveying for alpha, beta, or gamma contamination. Four ranges cover radiation intensity to 20,000 counts/min.

61 Axial Flow Agitator. For use with new or existing stock chests a Murco axial flow agitator. Requires no fresh water supply for lubrication. No bearing replacements. Affords varied capacities with one size impeller. Interchangeable parts. D. J. Murray Mfg. Co.

62 Ball Bearing Clutches. New general duty, heavy duty ball bearing overrunning clutches developed by Morse Chain Co. Avoids need for bearings to support ends of shafts that clutches control.

63 Temperature Equivalents Chart. Pocket size Fahrenheit & Centigrade temperature equivalents chart available from Moeller Instrument Co.

64 Strip Chart Recorders. Two electric strip chart recording instruments designed to record 10 & 20 points have been introduced by the Industrial Division of Minneapolis-Honeywell Regulator Co.

65 Scintillation Count Rate Meter. For use in a radioisotope laboratory new model scintillation count rate meter CRM-550 from Nuclear Research and Development, Inc.

66 Diaphragm Valve. Cooperating with antibiotic processors Hills-McCanna Co. developed a diaphragm valve for use in antibiotic plant operations. Easily maintained aseptic, meets high standards of cleaning & sanitation.

67 Control Panel. A centralized system for control of continuous polymerization reactors developed by Milton Roy Co. Uses 23 air-operated flow control pumps, for precise proportioning of feed streams, centralized control of process pumps, independent & automatic control of catalyst feed & integral operations monitor & warning system.

68 Instrumentation. Bulletin from Bailey Meter Co. on instrumentation for modern process plants. Includes specifications for measuring, transmitting, receiving, interpreting & controlling 18 variables encountered in production processes.

69 Submerged Combustion. Issued by Submerged Combustion Co. of America, Inc. a Subcomo Application Manual on use of submerged combustion equipment in various industries.

70 Volumetric Attachment. Developed by MRM Co., Inc. Manufacturers of liquid filling machines, a volumetric attachment for attachment to any filling machine. Accurate at high speeds to within tolerance of ± 1 gram

71 Eye Protection. Protection against flying particles & chemical splash, also light glare afforded by Mine Safety Appliances Co. Jones visor goggles. Design features opaque green visor with perforated or open type ventilation or two-port screened for indirect ventilation.

72 Non-Brittle Cement. Polymer Corp. has developed cement to meet need for tough, non-brittle bond between pieces of FM-10001 nylon. Called Nylaweld it is a liquid chemical mixture producing almost invisible joints.

73 Chart Paper & Ink. Designed especially for automation-minded industry is a new line of chart paper & ink from Minneapolis-Honeywell Regulator Company's industrial division.

CHEMICALS

85 Santocel. Silica aerogel by Monsanto Chemical Co. available in several grades. Uses described in booklet which includes general information.

86 Dispersing Agents & Surfactants. Five folders on products of Marathon Corp. cover dyestuffs, pesticides, industrial cleaners, water treatment, & leather tanning. Details & pertinent information on each.

87 Zeolex 23. Full details & compounding studies of Zeolex 3 a white reinforcing pigment available in brochure from J. M. Huber Corp. Compares material with calcium silicate in series of loadings with GRS, natural rubber. Used in plastics, rubber paints.

88 Anti-Settling Agent. Called Nuosperse 657 & available from Nuodex Products Co. an improved wetting, dispersing & anti-settling agent is discussed. Has auxiliary film-forming characteristics & no known deleterious effects on final product. Brochure includes table of physical constants.

89 Cation Exchange Resin. Data leaflet from Chemical Process Co. covers Duolite C-25 cation exchange resin—intermediate capacity sodium cycle, gives operating data.

90 Metal-Protective Process. Alodizing with Alodine No. 1200 is subject of folder from American Chemical Paint Co. Material provides effective protection for unpainted aluminum & durable bond for paint finishes. Increases natural corrosion-resistance of aluminum. Flow sheets & specifications.

91 Diisodecyl Adipate. Technical bulletin from Monsanto Chemical Co. on diisodecyl adipate a low volatile, low temperature plasticizer for polyvinyl chloride resins. Description physical properties, specifications.

92 Furan Cement. Resistance to chemicals, high physical strength & stability claimed for this furfural-ketone resin type cement by Pennsylvania Salt Mfg. Co. Two formulations—power S (siliceous filler) for general chemical service except in conditions involving hydrofluoric acid, free fluorides & strong alkalies; powder C (carbon-type filler) where such conditions occur.

93 Metal-Protective & Paint-Bonding Chemicals. From American Chemical Paint Co. check list of metal protective & paint bonding chemicals & processes.

94 Pyridine-N-oxide. Reilly Tar & Chemical Corp. are now processing commercial semi-works production of pyridine-N-oxide and 4-picoline-N-oxide. Presently used by pyridine chemists as major step to preparation of electrophilically substituted pyridines. Other oxide derivatives available.

95 IsoOctyl Decyl. Pittsburgh Coke & Chemical Co. now have available an IsoOctyl Decyl phthalate plasticizer with lower volatility & higher degree of permanence. PX-118 provides good performances in high temperature processing cycles & in calendering & coating operations which involve large surface areas. Imparts long life & good resistance to extraction by various materials.

Changes Announced in C. E. P. Staff

Van Antwerpen publisher—Mellecker editor

F. J. Van Antwerpen has been advanced to the position of publisher of the A.I.Ch.E., and J. B. Mellecker, Sr., advanced simultaneously to the post of editor of Chemical Engineering Progress.

In his new role Van, as he is best known to members of the Institute, will concentrate on the broader problems of carrying out an expanding Institute publishing program. His responsibilities will include all publications: C.E.P., the Monograph and Symposium Series, and the new A.I.Ch.E. Journal scheduled to appear quarterly in 1955, edited by Professor R. Harding Bliss of Yale. A Ch.E. graduate from Newark College of Engineering, following which he did graduate work at Columbia, Van has performed all aspects of editing and publishing activities in a career which began long before he joined the Institute at the time of founding C.E.P. Among his many activities, Van is a member of the advisory committee on industrial information for A.E.C., and Engineers Joint Council.

As the new editor of C.E.P., John Mellecker takes over the place vacated by Van Antwerpen. Brought into the staff as Associate Editor in February, 1954, John has been undergoing a thorough indoctrination for his new duties. Formerly senior technical editor of Chemical Engineering Catalog, he is widely known as a specialist on processing equipment. One of his most recent operations prior to joining C.E.P. was conducting field studies on information needs of chemical engineers. He is a graduate in Ch.E. from Iowa State College.

GLASHEEN JOINS C.E.P. AS ASSOCIATE EDITOR

R. W. Glasheen has been appointed to the staff of C.E.P. as associate editor specializing in field activities. Dick is an outgoing and friendly individual, and bears every promise of being able to carry, on his expanse of shoulders, the sizeable job of keeping up with goings-on in the field of chemical engineering. A graduate in engineering science from the University of Miami, Dick has had several years of experience as a process engineer in the field of electronic tube manufacturing. His work was mainly with the development of processing techniques for use in germanium and silicon semiconductor diodes and transistors.

GLENNON ADVANCED TO ASSOCIATE EDITOR

Helen R. Glennon has been advanced to associate editor of C.E.P. specializing in manuscript operations. Miss Glennon has been with C.E.P. since its beginning, and before this was on the editorial staff of McGraw-Hill. Known to the multitude of authors of Institute papers as one who has helped many make a gem out of a rough stone, Miss Glennon is an authority on styling and standards for technical publications.

National Meeting Report

(*Continued from page 42*)

"leaked" and by the time the contest was to begin, hundreds of spectators were present to witness what obviously was never intended to be a secluded fishing expedition. The pictures accompanying this report speak for themselves in conveying the dignity and restraint exhibited by such famous sportsmen of the trout world as are identified by the captions. It was indeed a spectacle of the highest order to witness—if somewhat wet for spectators. Winner of award for making the first catch: Publisher Van Antwerpen . . . for demonstrating the best of good fellowship: President Kirkbride. Anti-climax: Appearance of a fish and game warden, checking furtively for "licenses."

Calico and Calls. As the violin wheezed its warm-up strains, couples formed in facing rows. After a briefing complete with slow-motion dry runs, the square dance began in earnest. For nearly an hour the dance continued, with the pace building up until, after a number which appeared (certainly to the camera's eye) as a blur, the affair was declared ended. Many surprisingly unweary chemical engineers and their wives seated themselves for a brief respite and refreshment, only to return to the floor to round out the evening with "regular" dancin'.

Plant Trips. Visitors to the shale oil mine and experimental shale oil refinery of the U. S. Bureau of Mines at Rifle, Colo., saw the mahogany-colored rock removed by blasting, shovel and truck. Following a size-reduction step, the shale is retorted and the resulting oil then passed through a number of processing steps similar in outer appearance of equipment involved, to those used in conventional refining. Most interesting experience: Traversing the hairpin-turns of the mountain road between plant and mine.

The trip to Climax, Colo., and the Climax Molybdenum mine and plant was taken by two large bus loads of visitors including many ladies (see photo). The area in which Climax is situated is one of the most scenic parts of the Rockies, including a nearby pass nearly 12,000 feet in altitude. Included was a visit to Leadville, said to be the highest incorporated town in the U. S. (altitude more than 10,000 ft.). The plant trip included a visit to the mine, which operates on the novel principal of withdrawing ore from under a constantly caving-in overhead deposit. The operation is so large that at the time of taking the picture shown under the caption "plant trip," one of the buses was reported as "unlo-

(*Continued on page 76*)

National Meeting Report

(*Continued from page 74*)

cated." Outstanding event: The practical, down-to-processing talk given the visiting chemical engineers by Robert Henderson, resident manager (see picture).

The Climax Uranium plant trip had to be cancelled at the last minute. Through the graciousness of the U. S. Vanadium Corp. (Div. of Union Carbide), its plant at Rifle, Colo., opened its doors to visiting chemical engineers upon short notice, and provided a most interesting demonstration of rock processing and mineral dressing operations.

AUTHOR LOSES PAPER, IS JUDGED BEST IN PRESENTATION

Merritt L. Kastens was judged as having made the best presentation of a paper given at the Glenwood Springs meeting, according to D. I. Saletan, chairman, Committee on Paper Presentation Quality. The decision is made on the basis of audience attention and other evidence of interest created by the speaker, and does not rate the paper from the standpoint of its technical contents. Kastens achieved this recognition, incidentally, over major obstacles that might have unnerved some. The paper had to be delivered from notes as the manscript had been stolen along with his luggage from a parked automobile, shortly before he left New York. Then when finally enroute, he was delayed so long by mechanical difficulties with two consecutive airliners, he found it necessary to charter a private plane from Denver the morning of the presentation, in order to appear at the appointed time on the program.

Oil from Shale

(*Continued from page 38*)

deposit is believed to contain a total of 350 billion barrels. The "mahogany layer," which richly yields about 30 gallons of oil per ton, averages 100 ft. thick and is thought to contain a total of 100 billion barrels.

Experimental mining of the shale has been undertaken at the Bureau of Mines Experiment Station at Rifle, Colorado. Berg describes this as "room and pillar mining" which enters the deposit through the side of the bed exposed by a huge ravine. Trucks haul the shale to the crushing, retorting and refining facilities 2,200 feet below (5½ miles by winding road).

The processes which have been investigated to date differ in two respects—

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Oil from Shale

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in the separation of kerogen (which is a form of crude oil that is solid at ordinary temperatures) from the shale and in the refining of the shale oil. Studies since 1948-49 have succeeded, according to Berg, in reducing the cost of gasoline from shale from an estimated 18.7-22.5¢/gal. at that time, to a 1951 estimate of 14.7-16.2 ¢/gal., both assuming a return of 6% on capital investment (which is lower than conventional, in the petroleum field —editor). This compared in 1951 with petroleum gasoline at 12.0-12.6 ¢/gal.

The fundamental problem of how best to separate the kerogen from its inorganic medium was treated by three authors. Berg described a destructive distillation unit, together with related refining facilities, giving actual operating data. W. R. Thompson and C. H. Prien (Denver Research Inst.), on the other hand, reported on basic studies using solvent extraction working in the range of 200-400° C. According to Prien, much more remains to be investigated before the lowest economic limits can be established.

Another aspect which also contributes heavily to the cost is refining, which might conceivably be done by transporting the crude shale oil to existing refinery facilities. Studies by B. Morris and R. J. Cameron (U. S. Bureau of Mines), C. K. Viland (Tide Water Assoc. Oil) and R. L. Crecelius, E. O. Kindschy, C. B. Hopkins, H. C. Carpenter, C. M. Frost, E. R. White, G. C. Freeman and P. L. Cottingham (Bureau of Mines) have gone far in indicating to petroleum refiners which modifications of existing refining techniques will produce most efficiently, the desired balances of end products of either military or civilian nature.

As to when our nation will turn to these great resources, no one was willing to predict. Should, however, we be seriously threatened with another war in which great air, sea and mechanized land forces would have to be maintained indefinitely in the face of difficult sea-transportation of foreign petroleum crudes, then the answer seems obvious. . . .

Uranium from Ore

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of assistance to others engaged in the winning of other raw materials from mineral sources. R. H. Long's (Vitro Corp. of Amer.) symposium "Uranium Ore Processing and Refining" (con-

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Uranium from Ore

(*Continued from page 77*)

ducted in his absence by E. C. Sargent) represented a forward step towards realizing the above objectives. A classification of processes used according to the nature of ores, was presented by W. L. Lennemann (A.E.C.). Uranium is solubilized, according to Lennemann, by either acid or carbonate treatment of the finely ground ore. The choice depends upon the ore, and its content of solubilizing-interference substances, as well as the presence of any valuable constituents. Once the uranium is in solution, the following problems "are faced in accomplishing its recovery: Techniques and economics, slimes and liquid-solid separation, and problems of upgrading the initial uranium-bearing precipitate."

With Uranium—Vanadium. The miner of uranium ore, stated F. A. Brinker (Vanadium Corp. of America), receives pay for both vanadium and uranium content and "it is doubtful whether any producer could stay in business long without the pay for both." This explains the attention being paid methods for economically recovering the vanadium content, reviewed in Brinker's paper. Many methods giving good uranium recovery (presently most sought) also give good recovery of vanadium. With certain ores, however, attempts to improve uranium recovery have resulted in lower vanadium yields. This is cited as an incentive for further development. Furthermore, "It will be for the best interests of our present alloy steel age as well as for the best interests of our National Defense to . . . remove the vanadium in a concentrated product rather than leave it in the tailing for later treatment."

Groping into Leaner Fields. Many ores virtually unheard of only a few short years ago are now being processed for their uranium content, according to J. D. Moore and E. Berhsohn (Vitro Corp. of Amer.). This amounts to as little as a few tenths of a per cent U_3O_8, with other metals present in too low a concentration to permit simultaneous recovery. The carnotite ores previously worked for their vanadium content with uranium as a byproduct, have become valuable for their uranium content alone. Such has been the result of uranium's coming of age as a source of energy. The description of the process used at the Vitro Uranium plant at Salt Lake City, Utah, was presented. The plant produces uranium concentrate for sale to the A.E.C.

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Uranium from Ore

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Expanding Future. All eight uranium mills operating on the Colorado Plateau, with the exception of the Monticello, Utah, government mill, are owned and operated by private industry, according to R. L. Philippone (A.E.C.). A ninth is under construction at Shiprock, N. M., and is to be completed this year. Milling facilities at Moab, Utah, are being planned and further expansion in this area will doubtless occur due to the continuing discovery of new ore bodies in the 107,000 square mile area known as the "Big Indian District," which extends into Colorado, Utah, Arizona and New Mexico, as well as fringe areas of Wyoming, South Dakota and Montana. The operations at the Monticello mill, operated by the Galigher Company, were described by Philippone for the benefit of the problems to be met by this anticipated expansion.

Check that Ore. It is now possible to determine the uranium content of an ore in less than two hours, according to an x-ray spectrographic method announced by M. L. Salmon and J. B. Blackledge (Denver Research Institute).

Our Future Resources

(*Continued from page 39*)

major resource. Ewell's symposium was planned to bring up to date some of the most significant parts of the Paley Report. "Chemical Engineering," commented Ewell, "must improve upon our traditional methods of winning needed products, achieving reduction of costs as raw materials of lower content have to be employed."

Chemical Engineering Frontier. Extractive metallurgy holds many advantages over mechanical concentration methods, according to O. C. Ralston (Bureau of Mines). Principal of these is the ability to take into solution many elements simultaneously, individually precipitate them to get single products or groups of products that can be handled by existing metallurgical extractive methods. Extractive metallurgy, as a term, refers to hydro-pyro- and electrometallurgical operations. All consist largely of chemical processes. Their future, predicted Ralston, depends on developments arising from the application of modern chemical engineering unit operations. When these are properly applied, the tailings dumps of the present generation will become precious resources for future

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Our Future Resources

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generations. Many of the modern processes involve use of pressure vessel equipment, which are being demonstrated to metallurgists as entirely feasible. Filters and centrifuges are also coming into use for purifying metals, as are ion-exchangers, liquid-liquid extractors and other well known chemical engineering devices. In the case of ion exchangers, resin in solution form was mentioned, along with better known solid and diaphragm types.

Reprocessing Nuclear Fuel Essential. The responsibility for economical nuclear power rests primarily with the chemical engineer, stated M. L. Kastens (Stanford Research Institute), who posed the problem as one of finding the means for chemically reprocessing the spent nuclear fuel to permit the full utilization of its energy content. He predicted that present chemical firms will build and operate fuel refining plants immediately adjacent to nuclear power plants owned and operated by utility firms.

Mankind and Food. Each country, even the most densely populated, can support its own population with an adequate diet, according to P. D. V. Manning (International Minerals & Chemical Corp.). This would be accomplished only through the utilization of presently available aids such as soil chemicals, fungicides and insecticides, through attenuating certain religious tenets restricting diet, and through the development and use of a synthetic protein additive to supplement a purely vegetable diet.

Plastics to Grow. The volume of the plastics industry may very well get to be, by 1975, eight times its size in 1950, predicted C. E. Staff (Bakelite Co.). Plastic pipe was cited as expected to take over five to ten per cent of the total footage of steel pipe. Other examples of growing applications are: Telephone cable jacketing (replacing lead) and floor tiles (displacing linseed oil).

Chemical Engineering Metals. Aluminum and magnesium might both be termed such, inasmuch as both are made by chemical engineering processes, according to A. C. Byrns (Kaiser Aluminum and Chemical Corp.). Byrns further commented that magnesium would be in far greater demand, were it not for the excellent comparative properties of aluminum.

(More on Glenwood Meeting, page 81)

Agglomeration

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cited by Weber as to why agglomeration will be more widely used throughout the process and other industries, are: Improving cleanliness, avoid losses and unnecessary human contact, uniformity of resulting gas flow resistance and other properties.

Big User. One of the largest employers of agglomeration techniques is the fertilizer industry, particularly for the granulation of mixed fertilizers to reduce dusting, caking, segregation and to improve applicability. Consequently, studies on agglomerating fertilizers are revealing applied as well as fundamental data, both of which were reported on by J. O. Hardesty (U. S. Dept. of Agriculture). For mixed fertilizers, Hardesty proposes the following elements which should be taken into account for approaching process design: (1) types of formulas to be processed, (2) physical and chemical properties of the initial materials, (3) heat development and temperature rise due to ammoniation, (4) water requirement for optimum agglomeration, and (5) methods and equipment for measuring and controlling the moisture-temperature relationships during processing.

Low Grade Ore Applications. Efforts to satisfactorily process taconite ores for their iron content have required agglomerating by some means the fines resulting from beneficiation, which because of their extremely small particle size are not suitable blast furnace raw material. Objective has been to produce material in a form which is coarse, resistant to abrasion and impact, and yet is easily reduced in a blast furnace. Four means for agglomerating fine ores and concentrates over the years have become economically feasible: briquetting, sintering, nodulizing and pelletizing. S. R. B. Cooke (Univ. of Minn.) and T. E. Ban (Cleveland-Cliffs Iron Co.) reported on pelletizing studies. These entailed establishing optimum conditions for rolling damp fines in a drum, then firing in a furnace or on a grate the "green" balls so produced. Principal variables studied were binders and firing temperature and time.

Coal Applications. French coal mining operations, because of mechanization and particularly friability deposits, produce a large amount of fines. Agglomeration of these has therefore received considerable attention. A paper by J. Lusinchi and J. Charbonnier (Centre d'Etudes et de Recherches des Char-

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Agglomeration

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bonnages)—read in their absence by N. H. Parker (Turbo-Mixer Div., G. A. T. X. Corp.—reported on the briquetting practices of the industry, and on research into improved pitch-type binders and equipment. The latter includes investigation of open mold and ring presses.

Sonic Studies. R. S. Boyd (Cabot Carbon), E. J. Holland (Georgia Pigment, Inc.), C. A. Stokes (Godfrey L. Cabot) and J. E. Vivian (M.I.T.) reported what has probably been the most concerted attempt yet made to bring sonic (high frequency sound) agglomeration to commercial use—so far, without desired success. The frequency appearing to give optimum results was in the neighborhood of 1000 cycles per second. Dry sonic agglomeration gave about the same results as wet. Tests were made on various grades of furnace black.

Present Equipment. A review of existing equipment employed for agglomeration was presented by C. H. Chilton (McGraw-Hill); factors to be considered in the design and use of drum type pelletizers, by H. E. Rowen (Dwight-Lloyd, Inc., Div. Sintering Machinery Corp.).

PILOT EXTRACTION COLUMN FOR LOAN

A turbo-mixer-settler pilot extraction column for loan under special arrangement with customers has been designed and built by the Turbo-Mixer division of General American Transportation Corporation. The 8 ft. tall 6-in. diam. extraction column is complete with air-motor and speed indicator for piping directly to material streams being treated. A current use is in butadiene extraction with a copper solvent.

"CHEMICAL ENGINEERING FACULTIES" NEARING PUBLICATION

The 1954-55 edition of "Chemical Engineering Faculties" is being prepared for publication by the Chemical Engineering Education Projects Committee of the Institute.

nuclear engineering division

A communication dated Sept. 2nd from D. L. Katz, chairman and J. J. Martin, Secretary-treasurer of the Nuclear Engineering Division of A.I.Ch.E., carried the following announcement:

"The Engineers Joint Council have brought together representatives (presidents, secretaries, and Nuclear Energy Committee chairmen) of E.J.C. societies as well as the A.C.S. and the Amer. Institute of Physics at two meetings in July and August. J. R. Dunning of A.S.M.E. nuclear energy application committee, was asked to be chairman and D. L. Katz of the nuclear engineering division was asked to be secretary of a general committee to make plans for a cooperative effort in the nuclear energy field. A meeting of this committee is called for Sept. 20th."

Earlier, it had been announced by A.I.Ch.E. headquarters that "It is the sense of Council that in the field of nuclear energy our instrument of cooperation with other organizations meetings, symposia, etc. is the nuclear engineering division of A.I.Ch.E."

On Sept. 24th this office received a copy of the minutes of the general committee meeting, held by E.J.C. on Sept. 20th, and referred to above. A series of motions were made and passed as follows:

"1) It was the sense of the assembled group that they should cooperate with the presidential conference—if one is to be held in the U.S. in 1955. The committee would be willing to accept the responsibilities for the civilian aspects of the meeting.

"2) If a presidential conference is held in the U.S. in 1955, committees and divisions within individual cooperating societies should be urged to hold sessions devoted to nuclear matters at their regularly scheduled meetings in 1955 to give strength to nuclear divisions in the present societies.

"3) If the presidential congress is not held in U. S. in 1955, or is held abroad, a nuclear congress will be held under the auspices of the general committee of nuclear engineering and science.

"4) That the nuclear congress, organized by E.J.S's. general committee, hold a meeting on July 11-16, 1955 or December 12-17, 1955. After passing the motion and further exploration—the dates were mutually agreed as being the most satisfactory. It is recognized that July 11-16, 1955 might not be the proper date for cooperation with the presidential conference.

"5) The staff of E.J.C. was instructed to explore the possibilities of meeting locations, especially on college campuses and submit the information to the chairman and secretary of the general committee, who are authorized to choose the location in light of all information and views available.

"6) It is the sense of the group that E.J.C's. general committee should hold an annual nuclear congress at least for the next few years.

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FUTURE MEETINGS and Symposia of the Institute

MEETINGS **SYMPOSIA**

ANNUAL—NEW YORK, N. Y., Statler Hotel, Dec. 12-15, 1954.

Technical Program Chairman: G. T. Skaperdas, Assoc. Dir., Chem. Eng. Dept., M. W. Kellogg Co., 225 Broadway, N. Y. 7, N. Y.

ASST. CHAIRMAN: N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

Gas Absorption

Reaction Kinetics

Biochemical Engineering

Solvent Extraction

New Processes Utilizing Moving Beds

Business Organization for the Chemical Industry

Deadline Past

LOUISVILLE, KY., Kentucky Hotel, March 20-23, 1955.

Technical Program Chairman: R. M. Reed, Tech. Dir., Gas Proc. Div., The Girdler Corp., Louisville 1, Ky.

Heat Transfer

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

Propellant Power

CHAIRMAN: R. A. Cooly, Explosives Div., Olin Mathieson Corp., East Alton, Illinois.

Industrial Relations

CHAIRMAN: Samuel L. H. Burk, Dir. Personnel Administration, General Foods Corp., White Plains, N. Y.

Centrifugation

CHAIRMAN: J. O. Maloney, Chairman, Dept. Chem. Eng., Univ. of Kansas, Lawrence, Kan.

Deadline—November 20, 1954

HOUSTON, TEXAS, Shamrock Hotel, May 1-4, 1955.

Technical Program Chairman: J. L. Franklin, Res. Assoc., Humble Oil & Refining Co., P. O. Box 1111, Baytown, Texas.

Nucleation Processes

CHAIRMAN: D. W. Oakley, Plant Mgr., Metal & Thermit Corp., 1 Union St., Carteret, N. J.

Flow of Fluids Through Porous Media

CHAIRMAN: H. Dayton Wilde, Mgr. Res. Div., Humble Oil & Ref. Co., Box 2180, Houston 1, Tex.

Extractive and Azeotropic Distillation

CHAIRMAN: Dr. D. E. Holcomb, Dean of Eng., Texas Technological College, Lubbock, Tex.

Chemical Engineering Curricula

CHAIRMAN: Dr. J. W. Mason, Dean of Eng., Georgia Inst. of Tech., Atlanta, Ga.

Differences in Chemical Engineering Theory

CHAIRMAN: Dr. F. A. Landee, Dow Chemical Co,. Midland, Michigan.

Deadline—January 1, 1955

LAKE PLACID, N. Y., Lake Placid Club, Sept. 25-28, 1955.

Technical Program Chairman: L. J. Coulthurst, Chief Proc. Designer, Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

MEETINGS **SYMPOSIA**

Process Engineering Organizations

CHAIRMAN: J. F. Thornton, Pres., The Lummus Co., 385 Madison Ave., New York 17, N. Y.

Deadline—May 25, 1955

ANNUAL—DETROIT, MICH.—Statler Hotel, Nov. 27-30, 1955.

Technical Program Chairman: T. J. Carron, Supervisor, Chem. Eng. Section, Ethyl Corp., Res. Labs., 1600 West Eight Mile Road, Detroit 20, Mich.

Photochemical Processes

CHAIRMAN: Prof. J. J. Martin, Dept. Chem. Eng., Univ. of Michigan, Ann Arbor, Mich.

Biochemical Engineering

CHAIRMAN: Dr. H. O. Halvorsen, Dept. of Bacteriology, Univ. of Illinois, 362 Noyes Lab. of Chem., Urbana, Illinois.

Technical Societies Cooperation with Chemical Engineering Industries

CHAIRMAN: Prof. J. B. Phillips, Dept. Chem. Eng., Phys. Sciences Centre, McGill Univ., Montreal 2, Canada.

Deadline—July 27, 1955

LOS ANGELES, CALIF., Statler Hotel, Feb. 26-29, 1956.

Technical Program Chairman: T. Weaver, Proc. Eng., The Fluor Corp., Ltd., Box 7030, East L. A. Station, Los Angeles 22, Calif.

Deadline—Oct. 26, 1955

ANNUAL—BOSTON, MASS., Hotel Statler, Dec. 9-12, 1956.

Technical Program Chairman: W. C. Rousseau, Proc. & Sales Eng., Badger Mfg. Co., 230 Bent St., Cambridge 41, Mass.

Deadline—August 9, 1956

UNSCHEDULED

Extraction of Hydrocarbons for Chemical Use from Pipe Line Gases

CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

Bubble Mechanics

CHAIRMAN: Prof. R. C. Kintner, Dept. Chem. Eng., Ill. Inst. of Tech., 3300 Federal St., Chicago 16, Ill.

Fundamental Mechanisms in Boiling Cavitation and Condensation

CHAIRMAN: R. R. Hughes, Shell Development Co., Emeryville, Calif.

Extraction of Hydrocarbons for Chemical Use from Pipeline Gases

CHAIRMAN: E. Frye, J. F. Pritchard & Co., 210 W. Tenth St., Kansas City 5, Mo.

ONE-DAY ANNUAL SYMPOSIA

South Texas Section, Galveston, Texas—October 22, Galvez Hotel

AUTHOR INFORMATION

Submitting Papers

Members and nonmembers of the A.I.Ch.E. who wish to present papers at scheduled meetings of the Institute should follow the following procedure.

First, write to the Secretary of the A.I.Ch.E. Mr. S. L. Tyler, American Institute of Chemical Engineers, 25 West 45th Street, New York, requesting three copies of the form "Proposal to Present a Paper Before the American Institute of Chemical Engineers." Complete these forms and send one copy to the Technical Program Chairman of the meeting for which the paper is intended, one copy to the Assistant Chairman of the A.I.Ch.E., Program Committee, address at the top of this page, and one copy to the Editor of Chemical Engineering Progress, Mr. F. J. Van Antwerpen, 25 West 45th Street, New York.

If you wish to present the paper at a particular symposium, request 4 copies of the proposal sending a copy to the Chairman of the symposium.

Before Writing the Paper

Before beginning to write your paper you should obtain from the meeting Chairman, or from the office of the Secretary of the A.I.Ch.E., at 25 West 45th Street, New York, a copy of the A.I.Ch.E. Guide covers the essentials required for submission of papers to the A.I.Ch.E. or its magazines.

Copies of Manuscript

Five copies of each manuscript must be prepared. For meetings, one should be sent to the Chairman of the symposium, and one to the Technical Program Chairman of the meeting at which the symposium is scheduled. If no symposium is involved, the two copies should be sent to the Technical Program Chairman. The other copies should be sent to the Editor's office. All manuscripts submitted to the A.I.Ch.E. Editor are automatically considered for C.E.P., the A.I.Ch.E. Journal, and the Symposium Series. Presentation at a meeting is no guarantee that manuscripts will be accepted.

Chairman, A.I.Ch.E. Program Committee
George Armistead, Jr., George Armistead & Co.,
1200 18th St., N.W., Washington, D. C.

Assistant Chairman
L. J. Coulthurst, Foster Wheeler Corp.
165 Broadway, New York 6, N. Y.

Nuclear Engineering Div.

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"7) The chairman and secretary of the general committee were authorized to select locations of the congresses to be held in 1956 and 1957 during the first full week following July 4th."

It was further stated, in the minutes that: "D. L. Katz was selected at this meeting as chairman of the program committee . . ."

Also, "This general committee invites any qualified group interested in nuclear matters to cooperate with it. The plan is for these groups to work side by side in the holding of the annual nuclear congress with the activities coordinated by the general, program and publication committees sponsored by E.J.C."

Subsequently, for release Sept. 30th, 1954, this office received a news release from E.J.C. which began with the following headline:

"Engineers and chemists organize general committee on nuclear engineering and science to meet peace time problems and opportunities of industrial usefulness. Represents 240,000 members of nine major societies. Plan 1955 nuclear congress if U.N. conference urged by Dulles is held abroad. New committee headed by Columbia engineering dean." (J. R. Dunning—Ed.)

See "News and Notes," (page 102 of this issue), for more on same.

Just before going to press, the Oct. 12th issue of the *New York Times* appeared with the following announcement: "Scientists Organize a Nuclear Society; Washington, Oct. 11—

"The American Nuclear Society, the first wholly professional organization of scientists and engineers working in the atomic energy field, was formally established here today.

"The new group, which has yet to elect officers, promptly offered its cooperation to Rear Admiral Lewis L. Strauss, chairman of the United States Atomic Energy Commission, in arranging for the international conference on nuclear energy proposed by the Secretary of State, John Foster Dulles, before the United Nations General Assembly.

"United Nations sponsorship of such a conference, to be held in the United States next spring, is now under consideration.

"Admiral Strauss, in a congratulatory message to the founders of the society, said that 'every American should be encouraged by this demonstration of confidence in the future of the peaceful application of atomic energy on the part of scientists and engineers.'

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CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 8, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members will receive careful consideration if received before November 15, 1954, at the Office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

Member

Agapetus, N. A., *Port Neches, Tex.*
Allaire, Walter F., *New Orleans, La.*
Barkow, Carl W., *Oak Ridge, Tenn.*
Bice, Harold, *Penns Grove, N. J.*
Bond, J. M., *Houston, Tex.*
Bove, Henry J., *Havertown, Pa.*
Bramer, Henry C., *Pittsburgh, Pa.*
Brown, George Martin, *Evanston, Ill.*
Burdick, F. A., *New York, N. Y.*
Chapman, Harold D., *Paulsboro, N. J.*
Chilson, Francis, *East Chatham, N. Y.*
Direnga, Otto G., *Tenafly, N. J.*
Drisko, Thomas E., Jr., *Concord, Calif.*
Edwards, Edwin F., *Whittier, Calif.*
Finelli, Salvatore J., *Rahway, N. J.*
Frankel, Irwin, *Argo, Ill.*
Franklin, W. C., *Texas City, Tex.*
Frevert, James W., *Bound Brook, N. J.*
Georgian, Carl C., *Texas City, Tex.*
Hodge, John A., Jr., *Midland, Mich.*
Huscher, Myron E., *Midland, Mich.*
Kenda, William, *Honolulu, Hawaii*
Kennedy, Thomas I., *Houston, Tex.*
Kerley, D. J., *Rotterdam, Holland*
Kupp, Robert W., *Midland Park, N. J.*
Leeds, T. F., *Alton, Ill.*
Lefevre, Milton A., *Appleton, Wis.*
Luening, W. D., *S. Roxana, Ill.*
MacPhail, A. A., *Midland, Mich.*
Marty, Hubert H., *Avon Lake, Ohio*
May, J. A., *Lake Jackson, Tex.*
McCreery, Austin R., *Bellflower, Calif.*
McDonald, David, *Richland, Wash.*
McKenna, Cyril C., *Denver, Colo.*
Metcalfe, T. Brooks, *Houston, Tex.*
Morello, Victor S., *Midland, Mich.*
Osburn, James O., *Iowa City, Iowa*
Ossermann, Alan T., *Baltimore, Md.*
Pena, Isidro R., *Ashland, Ky.*
Peters, Arden A., *Rocky River, Ohio*
Pillai, V. S., *Alwaye, (U.S.T.C.), S. India*
Rice, Robert D., *Pittsburgh, Pa.*
Schaffner, Joseph G., *Baltimore, Md.*
Schmitt, Joseph B., *Pittsburgh, Pa.*
Spradling, Robert W., *Joliet, Ill.*
Stanton, C. H., *Mount Vernon, N. Y.*
Stone, Everett E., *Alexandria, Va.*
Swanton, Walter F., *Avon, N. Y.*
VanHouten, G. Robert, *Greenfield, Ind.*
Voorhies, Marcel J., Jr., *Baton Rouge, La.*
Waechter, Harvey C., *Lewiston, N. Y.*
Walko, Edward J., *Lakewood, Colo.*
Wasp, Edward J., *Mount Lebanon, Pa.*
White, Edward F., Jr., *Plainfield, Ill.*
Wilson, Theodore J., *Wilmington, Del.*
Woolnough, G. N., *Montreal, Que., Canada*

Associate

Alstad, Charles D., *Midland, Mich.*
Barnhart, James H., *Corpus Christi, Tex.*
Bhat, G. N., *Bangalore, India*
Bongiovanni, Richard M., *Washington, D. C.*
Cassaday, Howard L., *Bridgeton, N. J.*
Code, Russel K., *Perth, Ont., Canada*
Craig, Jack L., *New York, N. Y.*
Danielson, Gilbert L., *Pasadena, Tex.*
Daus, Donald G., *Maywood, Ill.*
Day, Evan E., *Swarthmore, Pa.*
DeMaria, Francesco, *Jersey City, N. J.*

Emge, Leonard E., *Kingsville, Tex.*
Erb, Paul W., *Evanston, Ill.*
Evans, J. T., *Orange, Tex.*
Fisher, Colman, *Oklahoma City, Okla.*
Fitzgerald, Walter E., Jr., *Batavia, N. Y.*
Glauz, Roy L., Jr., *Cleveland, Ohio*
Greve, Dale Rex, *Grand Rapids, Mich.*
Haidos, John C., *Hibbing, Minn.*
Hall, James A., *Rochester, N. Y.*
Helmers, E. Neil, *Griffith, Ind.*
Herber, Raymond R., *Hinsdale, Ill.*
Higgins, Irwin R., *Oak Ridge, Tenn.*
Hopper, Charles F., *Oshkosh, Wis.*
Horton, John P., *Richmond, Va.*
Huizenga, Keith G., *Indianapolis, Ind.*
Huskey, Joseph E., *Copperhill, Tenn.*
Katz, Kurt, *New York, N. Y.*
Keats, William A., *Brooklyn, N. Y.*
Kelley, W. E., *Philadelphia, Pa.*
Kneale, Donald N., *Chicago, Ill.*
Leahy, John D., *Cincinnati, Ohio*
Lieb, Allan E., *Barberton, Ohio*
Masumoto, Sachiyuki, *Fayetteville, N. Y.*
Mayer, Josef H., *New York, N. Y.*
Neukomm, Harry O., *Charleston, W. Va.*
Nicaud, Frederick Harvey, *New Orleans, La.*
O'Brien, Leo T., Jr., *Linden, N. J.*
O'Shanick, Peter, *Akron, Ohio*
Pierce, Carl W., *Pittsburgh, Pa.*
Rankl, Richard S., *Clifton, N. J.*
Reed, Robert L., *Antofagasta, Chile, S.A.*
Reynolds, Victor R., *Westport, Conn.*
Rogers, Kenneth L., *China Lake, Calif.*
Rosekrans, David deL., *Wayzata, Minn.*
Schmidt, Walter D., *Emerson, N. J.*
Smith, Edwin A., *Haines City, Fla.*
Smith, W. Alan, *Wilmington, Del.*
Stone, Lawrence H., *Brooklyn, N. Y.*
Streamer, Joseph G., Jr., *Blasdell, N. Y.*
Verba, Paul, *Toronto, Ont., Canada*
VonBodungen, Gus A., *New Orleans, La.*
Wickey, Robert O., *St. Louis, Mo.*

NEWS

(Continued from page 85)

INDUSTRY AWARDS CHEMICAL ENGINEERS

Seven industrial fellowships totaling $13,875 for advanced study and research in chemical engineering have been announced by Illinois Institute of Technology. The Mixing Equipment Company of Rochester, N. Y., award of $2,000 was given to Hugo Nielsen; Monsanto awarded $2,150 to George Falk; Harold A. Lindahl received the Standard Oil (Ind.) fellowship for $2,000; the Swift fellowship of $2,150 was given to Richard N. Miller; Gerald Robertson was the recipient of a $1,775 Crane Company grant; Shell Oil awarded $2,150 to Joseph D. Lokay; and The Chicagoland Paint Industries Association award of $1,650 went to Bart DiLiddo.

Institute's new display booth

The story of the Institute and its publications is told briefly and attractively in the new display fixture which was first used at the Instrument Show. Its colors are brilliant yellow against a bright blue. Cover of C.E.P. shown in the photograph is this, the October issue. Ruggedly constructed to last a long time, it will be displayed next during the New York Annual Meeting.

Nuclear Engineering Div.

(*Continued from page* 85)

"Representative W. Sterling Cole, Republican of upstate New York and chairman of the Joint Congressional Committee on Atomic Energy, said the society could 'do much to advance beneficent uses of the atom.'

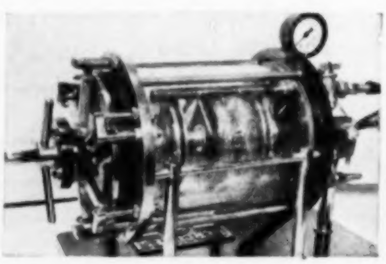
"The new group described itself as 'the world's first professional society of engineers and scientists representative of all scientific disciplines engaged in research, development and application of nuclear technology.'"

Mentioned as members of the organizing committee were, among others: J. G. Beckerley, W. M. Breazeale, K. Cohen, J. A. Lane and A. M. Weinberg.

Further developments will be reported as news is received.

NEW FILTER ANNOUNCED

Evaluation in a test filter of three different types of non-corrosive plastic filter materials simultaneously has been announced by Hercules Filter Corp. of Patterson, N. J. The new test filter which has a capacity of one-half foot is a replica of the large Hercules pressure leaf filter. Reaction of corrosive fluids to filter leaves made with acrylic, glass-reinforced polyester and polyvinyl chloride can be observed with liquid temperatures ranging as high as 300° F.



A.I.Ch.E. News of the Field — FROM LOCAL SECTIONS

Chicago Section. The Chicago section reports the election of the following officers for the year 1954-1955:

Chairman—R. H. Rogge (Corn Products Refining Co.)
Vice-Chairman—H. F. Nolting (Standard Oil Co.—Ind.)
Secretary—E. H. Vause (Standard Oil Co.—Ind.)
Treasurer—W. J. Alford (Pure Oil Co.)
Past Chairman—J. R. Blizzard (Transparent Package Co.)
Dir. at Large—R. A. Clarke (United Chemicals and ProOrganic Products Co.)
Dir. at Large—D. A. Smith (Swenson Evaporator Co.)
Dir. at Large—E. N. Mortensen (Swift & Co.)

—H. E. Gross

East Tennessee Section. The advantages of pumps that have no seals or stuffing boxes was the subject of a talk given by D. P. Litzenberg of the Chempump Corp., given to the East Tennessee Section on Sept. 29, 1954. Mr. Litzenberg reviewed early design efforts and a summary of the problems of cooling, metallurgy, corrosion and lubrication that are encountered in the development of a combined motor-pump. He outlined several new seal-less pump designs that are now beginning to appear on the market.

—M. L. Gernert

Savannah River Chemical Engineers' Club. The organization and problems associated with the construction of the atomic energy plant at Savannah River were discussed by R. W. Fulling of the E. I. du Pont de Nemours Co., at a Sept. 14 meeting in North Augusta, S. C., of the Savannah River Chemical Engineers' Club. Attendance was 75 persons. The club is preparing to apply for status as an active local section of the A.I.Ch.E. Since their beginning a year ago they have raised their membership to a total of 142.

—R. W. Hinterleiter

Baton Rouge Section. A new process tool—the Pebble Heater—for light hydrocarbon cracking and high temperature superheating was described by M. O. Kilpatrick to the Baton Rouge Section at a Sept. 16 meeting. Mr. Kilpatrick, who was in charge of the process design of the original unit for the Phillips Petroleum Co., outlined the pebble heater process, its various components and typical operating conditions and yield curves. Some

of the operating problems encountered and a few of the potential uses of the heater were reviewed. This unit was developed to obtain the higher yields of ethylene and acetylene which result from higher temperatures, shorter contact times and lower pressures than are normally realized in tube cracking furnaces.

—T. C. Landrum

New York Section. Acetylene plant design with particular reference to the Wulff process utilizing hydrocarbon gases as raw material, was the topic of M. J. P. Bogart in talk at a Sept. 21 dinner and meeting of the New York Section. Mr. Bogart is a process specialist and supervisor at The Lummus Co. and an adjunct professor at Brooklyn Polytechnic Institute.

—S. B. Adler

Western New York Section. The Annual Professional Achievement Award of the Western New York Section was given to G. D. Bagley at the Oct. 14 meeting held at Cutt's Hotel, Towanda, N. Y. Mr. Bagley, Chief Engineer of metals research, Electro Metallurgical Co., has contributed considerably to the advancement of the profession. He discussed in a topic "Forty Years of Research" some of his experiences in developing chemical processes among which were the production of calcium and magnesium. He has made major contributions to vacuum technology and to the atomic energy program. The award is given in recognition of outstanding service to local section and the national organization, and for outstanding contributions to the chemical engineering profession as a whole.

—F. A. Cox

New Orleans Section. The organization involved in engineering a European plant was discussed by J. Blickman of the Oronite Chemical Co. on Sept. 14 at a meeting of the New Orleans Section in the Engineers and Architects Club of New Orleans. Mr. Blickman, educated in the Netherlands, has held engineering positions in Europe and the Dutch East Indies.

—Alton S. Hall

National Capital Section. "The Future Energy Sources for Industry" was an address presented by Clifford C. Furnas, Chancellor of the University of Buffalo, at a dinner gathering of the National

Capital Section on October 6, 1954. The Dinner was held at the Officer's Mess of the Naval Gun Factory.

New Jersey Section. Stimulated by the vast amount of work required to handle a membership of 560 (which this section believes to be the largest in the country), the New Jersey Section amended their constitution to provide for both recording and corresponding secretaries. In reviewing their attendance record for this year the section reports an average attendance of 123.

—D. D. MacLaren

Tulsa Section. Discussion of underground storage of petroleum products was carried on at a panel meeting of the Tulsa Section on Sept. 23 at the University of Tulsa. The panel consisted of men employed by oil companies actively engaged in the use of underground storage facilities. They contrasted types of installation for cost of preparation and operation, and discussed types of products that can be successfully stored underground.

FORMATION OF NUCLEAR FIRM ANNOUNCED

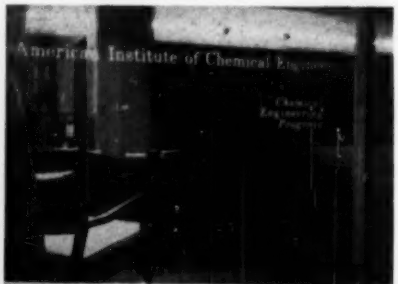
Former chairman of the Atomic Energy Commission, Gordon Dean, recently announced the formation of Nuclear Science and Engineering Corp. The company will contribute to the development of industrial nuclear energy by providing companies active in nuclear power and radioactivity applications with a variety of services such as radiation measurements, analyses, testing consulting, design, and research and development. Headquarters of the company have been established in Pittsburgh.

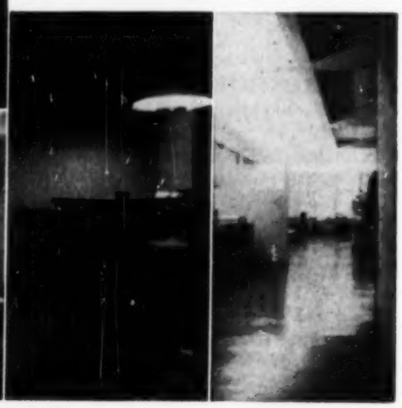
NEW METHOD OF INSULATING PIPE

A method of insulating pipe by wrapping it in magnesia insulation covered with factory-applied roofing felt has been devised by Du Pont. After the magnesia is clapped on the pipe, laps are cemented into position with asphalt cement and then stapled, a method that saves 6 to 7 min./ft. of installation time. The roofing felt may be coated with a vinyl resin emulsion paint to prolong the life of the insulation.

Institute's New Offices

On August 1st, the Institute moved to its new quarters at 25 West 45th Street, New York, N. Y. Remodeling having been completed, the staff is now enjoying having enough space for the various service functions performed for the swelling ranks of members. As a preview to what you are invited to come in and see-for-yourself during the New York annual meeting, the C.E.P. camera recorded these typical views:





top to bottom—

The entrance as seen from the elevators. Reception desk is at left, behind chair in foreground.

The reception room as seen by the receptionist. Note modern, but comfortable furnishings. Walls are warm grey, with some areas Williamsburg blue.

Corner of Executive Secretary's office, showing desk in background.

Another section of Executive Secretary's office. Conference table seats six.

View of open section of editorial office. In extreme background is editor's office. Outside are various desks handling communication, production, field news, etc.

Bottom center—

Partial view of conference room, which opens off hall leading between reception room and editorial offices.

Bottom right—

General view of Institute services offices, which run the width of the building. It is in this section that membership, mailing, storage, accounting and other operations are performed.

PEOPLE

F. C. Vilbrandt

After approximately twenty years as head of the department of chemical engineering at Virginia Polytechnic Institute, Blacksburg, Va., Frank C. Vilbrandt resigned effective Sept. 1, 1954. However, he will retain his teaching assignments.

Dr. Vilbrandt has a wide and diversified experience. He served as consultant to industrial plants in Virginia, Kentucky, North Carolina, Tennessee, Oklahoma, Louisiana and Iowa, turned his talents in design engineering to good account in chemical plants in almost as many different states. As a chemical engineer he was associated with the Iowa Engineering Experiment Station, Iowa State College; Engineering Experiment Station at Virginia Polytechnic Institute, and the Manhattan Project at the S.A.M. Laboratories, New York.

The author of many technical articles and of "Chemical Engineering Plant Design," Dr. Vilbrandt served as Councilor, Oak Ridge Institute of Nuclear Studies representing Virginia Polytechnic Institute.

Dr. Vilbrandt received his Ph.D. degree from Ohio State University. Prior to his going to Virginia Polytechnic, Dr. Vilbrandt spent fifteen years as head of the department of chemical engineering at University of North Carolina—a department he organized and developed there, and was a professor at Iowa State.

The promotion of **Jack M. Andrews** to senior research chemist in research and development division at its Baytown, Tex., refinery has been announced by Humble Oil & Refining Co. Formerly assistant research chemist, Mr. Andrews, in his new position, will be concerned primarily with investigations in the fields of catalytic cracking and the fluidized solids technique. Mr. Andrews received the B.S. degree in chemical engineering at A&M College of Texas in 1947, and the M.S. in 1948.

Harry W. Prendergast is now on the staff of the Esso engineering department, Standard Oil Development Co., Linden, N. J. He received his bachelor's degree in chemical engineering from the University of New Hampshire.

Marvin M. Ramer has been appointed manager of sales promotion, chemical plants division, Blaw-Knox Co., Pittsburgh, Pa. He was formerly contract manager of the division's Western headquarters at Tulsa. Prior to joining Blaw-Knox five years ago, he held several managerial and technical positions in the chemical industry. A graduate in chemical engineering from Rensselaer Polytechnic Institute, Mr. Ramer has done graduate work at Columbia University. While in Tulsa, he was section chairman of the A.I.Ch.E.

Max Key, who has been in charge of the Saran-polyvinyl chloride section, The Dow Chemical Co., Midland, Mich., has been promoted to the newly established position of assistant production manager in charge of the department's Midland production operations. He will have administrative responsibility for production in the cellulose, Saran, Styron and vinyl toluene sections.

Howard V. Smith was recently named vice-president in charge of refining of the Kendall Refining Co., Bradford, Pa. He joined the company in April, 1943, as refinery manager, and in December, 1944, he was elected to the board of directors. A graduate of the University of Kansas, he holds the degree of bachelor of science in chemical engineering. Prior to joining Kendall, Mr. Smith was assistant superintendent of refining for the Skelly Oil Co., El Dorado, Kan. Later he joined the Barber Asphalt Corp., Barber, N. J., as its director of research and development. Immediately prior to joining Kendall, he was project engineer in the synthetic rubber division of the Lummus Co., N. Y.

Calvin L. Dickinson, advisory engineer, American Potash & Chemical Corp., Trona, Calif., has been named director of engineering. In this capacity he will direct all Trona engineering functions, including power, maintenance, construction, and stores. Prior to joining the company in 1953 he was plant manager of the organic chemicals division of Diamond Alkali Co., Houston, Tex.

Robert H. Bauknecht has joined the staff of the Whiting Research Laboratories of the Standard Oil Co. (Ind.). Prior to this association he was with the DuPont Co. He received his bachelor's degree at the University of Colorado and his master's degree in chemical engineering at the University of Notre Dame.

The appointment of **Stuart Blake Row** as technical director in charge of all plastics and rubber research, development, and engineering has been announced by O'Sullivan Rubber Corp., Winchester, Va. Dr. Row received his B.S. and M.S. degrees in chemical engineering from Virginia Polytechnic Institute and holds a doctorate in chemical engineering from Ohio State. Following a research fellowship at Virginia Polytechnic Institute in 1931-32, he served as instructor and assistant professor at Virginia Institute and Ohio State University, and subsequently as professor and head of chemical engineering at Southwestern Louisiana Institute, Lafayette, La. A research chemical engineer with American Viscose Corp., Roanoke, Va., since 1942, Dr. Row's final position before his appointment by O'Sullivan was assistant technical superintendent.

J. H. HAYNER WITH DAY & ZIMMERMANN

Joseph Hayner has recently become associated with Day & Zimmermann, Inc., Philadelphia, Pa., as a staff consultant on nuclear engineering. In his new assignment he will be concerned with directing the company's activities in the industrial participation program. Mr. Hayner was formerly manager of the atomic energy division, Kaiser Engineers, division of Henry J. Kaiser Co., Oakland, Calif., and while out West was active in promoting interest in the recently formed Division of Nuclear Engineering, A.I.Ch.E., especially in winning new members.

With a broad experience professionally, Mr. Hayer has been associated with Leeds & Northrup, DuPont, American Locomotive, Bendix Aviation, Ford, and Bacon & Davis, before going to the U. S. Atomic Energy Commission in New York, in 1946.

Irwin L. Adler has joined the research unit as an associate technologist in engineering research at General Foods Central Laboratories, Hoboken, N. J. He received his B.Ch.E. degree from Newark College of Engineering, and his M.Ch.E. from New York University. Prior to his new appointment he served on the faculty of New York University.

Gustave E. Kidde has recently resigned from Filtrol Corp. as director and vice-president in charge of mining and manufacture.

CHEMICAL ENGINEERING PROGRESS

monograph

Nuclear Engineering—Part III

This final volume in the nuclear engineering series covers the rest of the papers from the Ann Arbor meeting (Symposium Series No. 13, 275 pages; $3.25 to members, $4.25 to nonmembers). The three Symposium Series volumes on nuclear engineering contain, with the May issue of C.E.P., all the papers presented at the first international congress on the peacetime uses of atomic energy, held at Ann Arbor, Mich., in June, 1954.

& symposium

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2. **Phase-Equilibria—Pittsburgh and Houston** (138 pages; $3.75 to members, $4.75 to nonmembers)
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7. **Applied Thermodynamics** (163 pages; $3.25 to members, $4.25 to nonmembers)
8. **Communications** (57 pages; $1.00 to members, $1.50 to nonmembers)
9. **Heat Transfer—Research Studies for 1954** (67 pages; $1.50 to members, $2.25 to nonmembers)
10. **Collected Research Papers—for Spring 1954** (142 pages; $3.25 to members, $4.25 to nonmembers)
11. **Nuclear Engineering—Part I** (280 pages; $3.25 to members, $4.25 to nonmembers)
12. **Nuclear Engineering—Part II** (259 pages; $3.25 to members, $4.25 to nonmembers)

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Walter N. Alexander was recently appointed director of operational planning of the dyestuff and chemical division of General Aniline & Film Corp., New York. Formerly director of technical planning on the division's manufacturing staff, Mr. Alexander has been responsible for directing the plans of the new chlorine-caustic plant to be erected at Linden, N. J. He joined General Aniline in 1946 and was appointed manager of the chemical engineering department in 1948. Prior to joining General Aniline he was employed in various phases of project design work with the General Chemical Co.

Douglas S. Sherwin, formerly chief, production control branch, Office of Synthetic Rubber, has been appointed secretary of the Federal Facilities Corp., the agency of the government designated to administer the government's synthetic rubber and tin programs. He is on loan from Phillips Chemical Co., Bartlesville, Okla.

J. B. Charlton, presently with the nylon information group of Chemstrand Corp. at Wilmington, Del., was recently appointed to the research and development center of the corporation at Decatur, Ala. He received his B.S. degree in chemical engineering from Alabama Polytechnic Institute, Auburn, Ala., and previously was associated with Arkansas Fuel Oil Co., Shreveport, La., and at Carthage, Tex.

J. J. O'Neill, Jr., has recently been appointed to the newly created position of assistant to the general manager of the explosives division of Olin Mathieson Chemical Corp., East Alton, Ill. He has been with Olin since 1940 when he was appointed project engineer in the smokeless powder laboratory of the Western Cartridge Company, becoming supervisor of the smokeless powder laboratory in 1942. Assistant manager in 1945, Mr. O'Neill was made manager of research and development for the explosives division in 1948.

Fred W. Emhardt has been appointed chief engineer of Struthers Wells Corp., Warren division. He has been with the corporation since 1936 in design and sales engineering and was recently assistant manager of the process equipment department. Prior to going with Struthers Wells, Mr. Emhardt spent six years in plant operations with the Solvay Process Corp., Hopewell, Va.

W. E. KUHN ADVANCES WITH TEXAS COMPANY

An announcement has been made to the effect that Wayne E. Kuhn is now general manager of the newly created research and technical department of the Texas Co. His present appointment fills a new executive post. Dr. Kuhn had been manager of the technical and research division since September, 1938. He joined The Texas Co. in 1929, and after eight years at the Port Arthur, Tex., refinery of the company, he was transferred to New York headquarters. Dr. Kuhn holds a Ph.D. in chemistry from Cornell University. Last year Dr. Kuhn was president of the Commercial Chemical Development Association.

Robert M. Aude is now plant manager of the Garfield, N. J. plant of the Heyden Chemical Corp. He has been manager of Heyden's Fords, N. J. plant since 1953. Prior to joining Heyden, Mr. Aude served in various production and supervising capacities with Monsanto Chemical Company from 1939 to 1953. He is a graduate of the University of Wisconsin with a B.S. degree.

The appointment of **Alfred J. Oxenham** as sales development manager, coal chemicals division, Pittsburgh Coke & Chemical Co., was recently announced. In this capacity he will be responsible for coordinating the activities of the coal chemicals division in expanding sales and finding new markets for present products. Prior to joining the company in 1950, he was a sales representative for the Merrimac Division of the Monsanto Chemical Co.

Robert L. Jacks accepted a new position as project engineer in the executive offices of the M. W. Kellogg Co., New York, N. Y., effective Sept. 27. He formerly was design engineer with the Esso Standard Oil Co., Louisiana Division, Baton Rouge, La.

The Tubular Exchanger Manufacturers Association has announced the appointment of **Karl A. Gardner** as chairman of its technical committee. He was graduated from Massachusetts Institute of Technology in 1934 with a B.S. degree in chemical engineering and did graduate work at Columbia University. He joined the Griscom-Russell Co., Massillon, Ohio, in 1936 and was appointed chief engineer in 1952.

(More About People on page 99)

CLASSIFIED SECTION

Address Replies to Box Number Care of CHEMICAL ENGINEERING PROGRESS

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Excellent opportunity in central engineering department. Prerequisites: degree in chemical engineering, six to ten years' experience in actual chemical process design with emphasis on light hydrocarbon and petrochemical fractionation problems. Positive personality and leadership potential required. Send complete résumé including recent photograph to:

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Cleveland 14, Ohio
(Attention: Mr. D. L. Thompson)

CHEMICAL PROCESS DESIGN ENGINEER

Excellent opportunity in central engineering department. Prerequisites: degree in chemical engineering, six to ten years' experience in heavy inorganic chemical plant design including material balances and design calculations and development of specifications for major items of equipment. Engineering experience in soda-ash production facilities is desirable. Potential and desire to adjust to engineering position involving considerable administrative responsibility must be evident.
Send complete résumé including recent photograph to:

DIAMOND ALKALI CO.
300 Union Commerce Building
Cleveland 14, Ohio
(Attention: Mr. D. L. Thompson)

PROCESS ENGINEERS

Chemical engineers with advanced degrees required for process design and evaluation work. Minimum five years' experience in process design of petroleum or organic chemical facilities required. Send complete résumé to Box 3-10, Chemical Engineering Progress.

CHEMICAL ENGINEER—Technical sales work. Experience in chemical and food processing with regard to vacuum or pressure filtration is desirable but not essential. Good opportunity. Salary and commission. California location. Write giving full particulars and include photo to: The Eimco Corporation, P. O. Box 240, Berkeley, California.

CHEMICAL ENGINEER

Opportunity for graduate chemical engineer to join intermediate-sized engineering company, New York City location, for work in process development, process design, evaluation and cost estimation, mainly in a wide field of organic and petrochemicals. Three years' similar experience required. Some plant-operating experience desirable. Replies confidential. Send résumé with full particulars and salary expected to Box 5-10.

CHEMICAL ENGINEERS

Immediate openings for chemical engineers with zero to five years' experience to assist in process design and development for this industrial consulting firm which has been conducting research programs for the leaders of United States industry since 1886.

Our staff are making careers in industrial research and enjoy:

- **Variety of work because of a continuous flow of challenging new assignments.**
- **Association with outstanding men in all scientific and technological fields.**
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Please send complete résumé and desired salary to Personnel Director

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30 Memorial Drive
Cambridge, Massachusetts

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Midwest engineering and construction company seeking graduate mechanical or chemical engineers with several years' mechanical engineering experience for assignments in recently expanded process division. These positions involve the direction and coordination of design, assistance in sales pertaining to engineering services, and the maintaining of good client relationships. One of the positions open requires a man who has had recent experience in supervising the design of synthetic- fiber- or rayon-producing facilities.

Positions offer long-term employment with attractive salaries, paid vacation and holidays, sick leave allowance, and company-sponsored group-insurance program.

If you feel your background qualifies you for this position, please submit complete résumé stating experience, education and salary requirements. All replies will be treated in a confidential manner. Interviews arranged for qualified applicants. Box 4-10.

PROCESS ENGINEERS—Permanent positions available requiring a Ch.E. degree and three or more years' experience in process design and development of oil refinery or chemical plant units. These are excellent opportunities to join an organization known throughout the world for accomplishments in these fields; located on the East Coast. Traveling and moving expenses paid. Please submit complete résumé and state initial salary desired. Box No. 423, Room 1201, 230 West 41 Street, New York 36, N. Y.

PILOT-PLANT DEVELOPMENT ENGINEERS—Large research laboratory associated with industrial plant in western New York requires chemical engineers to assume responsibilities of chemical pilot-plant development. Scope of engineering activity will involve design of medium to large-scale equipment for carrying out mainly inorganic chemical processes, construction and operation of such equipment, evaluation of the facility's function and efficiency, determination of required design alterations, and supervision of laboratory personnel. Applicants should have one to five years related experience. Please send outline of qualifications, personal background, and education. Box 2-10.

SITUATIONS WANTED

A.I.Ch.E. Members

CHEMICAL ENGINEER—B.S. 1941. Thirteen years' experience in economic evaluation, process design, and operation of petrochemical and nitrogenous fertilizer plants. Desire position in small organization with incentive program. Present salary $10,000 added. Box 1-10.

CHEMICAL ENGINEER—B.S.Ch.E. 1952. 2½ years' experience in plant operation, production supervision, pilot plant design and operation, quality control, and process improvement. Married, occupational draft deferment. Technical sales or production position in Midwest or Chicago area is desired. Box 6-10.

CHEMICAL ENGINEER—B.Ch.E. 1951. Age 26. One year's varied experience in research and development and package engineering. Will relocate. Box 7-10.

DIRECTIONS FOR USE OF CLASSIFIED SECTION

Advertisements in the Classified Section of Chemical Engineering Progress are payable in advance at 15c a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. Members may enter more than one insertion at half rates. Prospective employers and employees in using the Classified Section of Chemical Engineering Progress agree that all communications will be acknowledged; the service is made available on that condition. Boxed advertisements are available at $15 a column inch. Size of type may be specified by advertiser. Answers to advertisements should be addressed to the box number, Classified Section, Chemical Engineering Progress, 25 West 45th Street, New York 36, N. Y. Telephone COlumbus 5-7330. Advertisements for this section should be in the editorial offices the 15th of the month preceding publication.

B.Ch.E.—1941. Age 34, family. Ten years' excellent experience in organic field including process design and cost evaluation. At present development-department manager with successful record of responsible supervision. Desire opportunity in Mid-Atlantic area. Minimum salary $8,000. Box 8-10.

YOUNG CHEMICAL ENGINEER—M.S. 1949. Would like to make a change from an academic to an industrial laboratory. Am seeking position in research, development or pilot plant. Excellent background and references. Veteran, age 30, married. Box 9-10.

CHEMICAL ENGINEER—Age 37. Thirteen years' experience in plant and equipment design. Strong on heat transfer, evaporation, and distillation. Desire position as process or development engineer or in equipment sales. Box 10-10.

CHEMICAL ENGINEER—3½ years' experience in nuclear engineering process design, pilot plant development, and instrumentation. M.S.—M.I.T. Desire position with consulting firm or industry established in or initiating atomic energy work. Box 11-10.

PROCESS ENGINEER—Age 34. M.Ch.E. 1951. Ten years' diversified experience—plant engineering, production, development, one year as project engineer, three years with reputable design and construction engineering firm. Desire position with engineering firm in New York City. Box 12-10.

CHEMICAL ENGINEER—Ten years' diversified experience in synthetic fuels, petroleum refining, ammonia, and petrochemicals with emphasis on process design, economic evaluations and cost studies, and company diversification activities. Present assignment as assistant to executive at salary of $10,000 a year. Seeking position with aggressive oil or chemical company. Box 13-10.

CHEMICAL ENGINEER—B.S.Ch.E. Age 32, married. Three years' development experience in paper field, two years as process chemical engineer (heavy chemicals), one year fabricating and testing of friction materials. Desire responsible position in paper industry. Box 14-10.

CHEMICAL ENGINEER—Five years' experience in pilot plant, development, and plant trouble shooting. B.Ch.E. 1949. Age 29, married, family. Desire a challenging position with a future. Will relocate. Box 15-10.

DEVELOPMENT SUPERVISOR—B.S.Ch. 1939 with honors. Fifteen years' proven achievement in rayon process development, process economies and product improvement, and production start-ups. Eight years as pilot plant supervisor. Desire challenging opportunity with progressive company. Age 36. Eastern area preferred. $9,000. Box 16-10.

SALES ENGINEER—M.Ch.E. Age 37. Desire position in sale of heat exchangers, pressure vessels, process equipment, etc. Six years' design and eight years' sales experience. Metropolitan New York area preferred. Box 17-10.

CHEMICAL ENGINEER—M.S. in Ch.E. Age 35. Thirteen years' diversified experience pilot-plant and full-scale production supervision. Desire challenging administrative position in chemical manufacturing organization. Southern or Western location preferred. Box 18-10.

ADMINISTRATIVE, ORGANIZATIONAL, OR EQUIPMENT SALES position desired by chemical engineer. B.S. Age 34, family. Eight years' development, process and project design and engineering; production and construction supervision. Proven organizational and leadership abilities. Box 19-10.

Nonmember

B.S. in Ch.E. 1948—With six years of sound, useful experience in research, development and manufacturing technical service would like challenging position leading to greater responsibility and advancement. Box 20-10.

THE MROZ's OPEN CONSULTING OFFICE

Meet Edmund Mroz and spouse who entered into a new partnership on October 1 when they opened an office in Melrose, Massachusetts, to serve as consultants to small and medium-size New England industries. After eight and one-half years, Mr. Mroz left the process engineering department of Stone & Webster Engineering Corporation, Badger Process Division. His wife, the former Ann G. Buron, had earlier been employed with him in chemical engineering work in the process engineering department of the former E. B. Badger & Sons Company. Both are members of A.I.Ch.E.

Mr. Mroz has gained wide experience since World War II in all phases of process and project engineering: has started up major oil refinery and chemical plant installations in this country and abroad, served with the Office of Strategic Services, worked in bacteriological and chemical warfare projects, and in realistic training programs for the replacement of combat crews.

Mrs. Mroz was graduated from Tufts College with a B.S. degree in chemistry. Both she and her husband worked on bubble-tray research. In collaboration with others, she presented a paper on this subject before the A.I.Ch.E. meeting in Los Angeles in 1949, titled "Aerated Flow Principles Applied to Sieve Plates." For the past five years Mrs. Mroz has been engaged in raising three future chemical engineers (?).

The appointment of **David P. Barrett** as sales manager of the industrial chemicals department, Davison Chemical Co., division of W. R. Grace & Co., was recently announced. He joined the company in 1946 as a sales trainee in the industrial chemicals department, became a field salesman in the Midwest, and in July, 1949, took over the New York sales office. Immediately prior to his new assignment he was assistant sales manager.

Necrology

Chemical Engineering Progress recently heard of the death of the following members:

Geoffrey Broughton, chairman of the department of chemical engineering, University of Rochester, Rochester, N. Y. Born in England, he received his bachelor and master degrees from the University of London, and a doctor of science degree from the Massachusetts Institute of Technology. Dr. Broughton served Eastman Kodak Co. as a chemical engineer but left that concern during World War II to join the Office of Scientific Research and Development as a liaison officer at the United States Embassy in London. However, he returned to Kodak in 1945 and was appointed assistant superintendent in the paper service department. Four years later and until he became associated with the University of Rochester in 1952, he served as chairman of the department of paper engineering at Lowell Technological Institute in Lowell, Mass., where he remained for three years. Dr. Broughton was a member of A.I.Ch.E. Chemical Engineering Education Projects Committee.

Arthur Grundmann, who was with the U.S. Army at the Dugway Proving Ground, Dugway, Utah. He was formerly associated with Hercules Powder Co. as a chemical engineer. Mr. Grundmann was a graduate of Lehigh University.

Marion F. Dick, senior engineer in the technical division, textile fibers department, Du Pont Co., Waynesboro, Va. He held a B.Ch.E. and an M.S. from Ohio State University and a Ph.D. from the University of Michigan. For a short while as a graduate student he served as works chemist at the Capital City Products Co. and at the University of Michigan.

Frank Harvey Bailey, chief of research and development, Conolite division, Continental Can Co., Milwaukee, Wis. Prior to his accepting employment from the Continental Can Co. in 1952, he was associated with the American Cyanamid Co., Newcastle, Pa., in the explosives division. A graduate of Lehigh University in chemical engineering in 1941, Mr. Bailey was active in standards committee work for the Society of the Plastics Industry.

Frank Austin Lidbury, formerly works manager, Oldbury Electro-Chemical Co., Niagara Falls, N. Y. Born in England, Mr. Lidbury spent all his professional life in this country with Oldbury. At one time he was president of the Electrochemical Society.

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A.I.Ch.E. News And Notes

Creation of committees for specific functions always requires clear proof of necessity to Council, which is always critically studying the need for existing committees.

That it will dissolve such groups when necessary has been demonstrated in the past, & this month's Council meeting saw the end of the Nuclear Engineering Committee.

Reason is the vitality of the A.I.Ch.E. Nuclear Engineering Division begun last year. In disbanding the Nuclear Engineering Committee, Council transferred to the new division, responsibility for representing A.I.Ch.E. They voted "that it is the sense of Council that in the field of nuclear engineering our instrument of cooperation with other organizations, meetings, symposia, etc., is the Nuclear Engineering Division of the A.I.Ch.E.," & also that "all symposia and papers in the nuclear field ... should be developed by ... the division in cooperation with the Program Committee."

One of the first tasks of cooperation for the division is with Engineers Joint Council, which now plans for a congress similar to that held at Ann Arbor by A.I.Ch.E., but which takes in nine societies ... secretary of the general committee is D. L. Katz of the University of Michigan & he is also chairman of the cooperative movement's program committee.

Cooperation with E.J.C. does not preclude symposia on nuclear engineering at A.I.Ch.E. meetings by the division ... tentative plans are already under way for an all-day symposium at the Detroit meeting in November next year.

E.J.C. format for the Nuclear Congress calls for each society to develop its own portion of program.

Awards Committee working under Chairman Dick Wilhelm of Princeton advised Council of its choices for this year's awards.

This group has a heavy judicial task & must weigh many factors each year to determine who are to be honored ... proposal was made in Council by George Holbrook that a method be instituted between the editorial department & Awards Committee to transmit reviewers' opinions on papers to the committee to aid evaluation.

Nomination procedures mentioned last month in this column have given the Nominating Committee difficulty & members may be asked to vote a change. Constitution now allows nomination by petition not later than nine weeks before Annual meeting; final slate by seven weeks & ballot mailed not later than five weeks prior to Annual meeting. This allows only two weeks for consideration by the committee of the complete slate & two further weeks for collection of data on candidates, preparation of ballot booklets, candidate publicity in C.E.P., mailing, etc.

Problem of proper publicity for candidates, preparation of ballot booklets and time to collect pictures & career information is most serious shortcoming of the present amendment. Since candidates should be publicized in the October issue of C.E.P., final information should be in editor's hands no later than September 15th. Hence the need for an earlier ballot deadline.

Lee Van Horn of Nominating Committee made preliminary motion that closing date for nomination by petition be changed from nine weeks prior to the Annual meeting to eighteen weeks. This will come up for further debate at several Council meetings before it is presented to members.

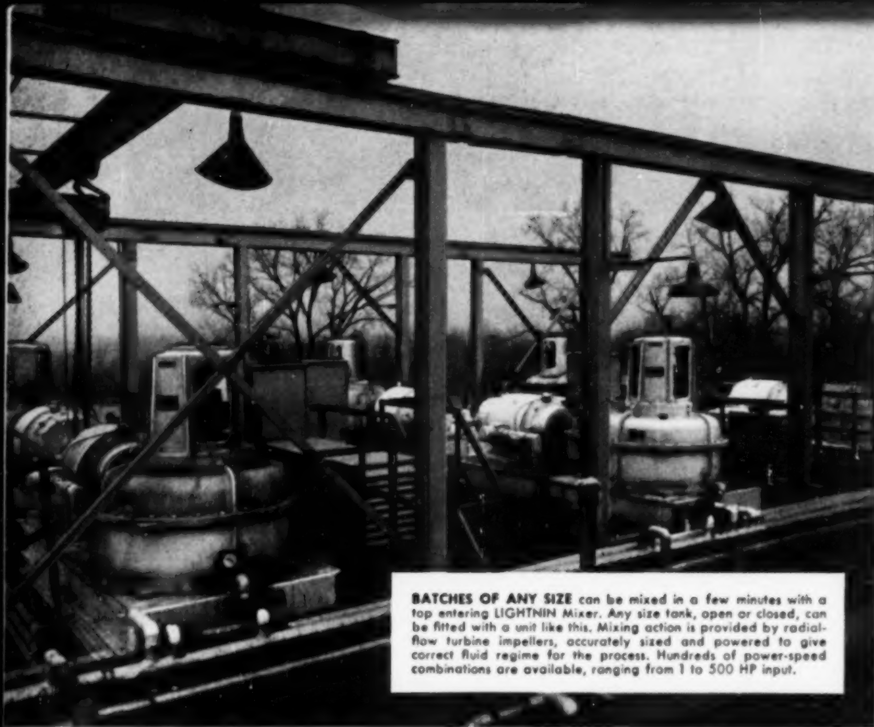
Vocational Guidance Committee through liaison member, Vice President B. F. Dodge, reported on activities ... C. B. Roen is chairman ... committee now has forty-two local section representatives acting as liaison between the national committee & local groups.

General planning group is now working on long range programs on guidance ... guidance materials have been sent to local section representatives and a program, in cooperation with other engineering groups, of supplying guidance information to science teachers is under way in St. Louis.

Marshall Monograph stemming from fourth institute lecture on "Spray Drying and Atomization" will be ready in time for the annual meeting. This is the second volume in the C.E.P. Monograph Series.

A.I.Ch.E. has agreed to take over the functions of Liquid Metals Committee formerly an adjunct of the Navy & the A.E.C. Idea is to run symposia on liquid metals techniques at A.I.Ch.E. meetings ... C. F. Bonilla of Columbia University is investigating possibility ... Institute will also publish the Liquid Metals Handbook as a Symposium or Monograph Series volume.

F.J.V.A.



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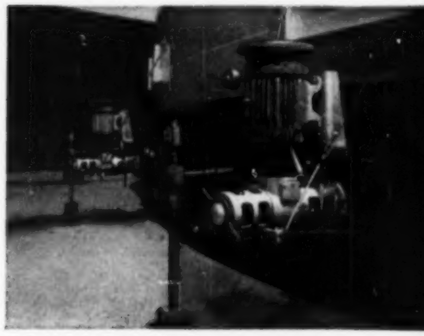

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